HOW TO SELECT THE RIGHT FERRITE BEAD FOR FILTERING DC/DC CONVERTER

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WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

PUBLIC

OUR AIM TODAY

- Lets see what we can do to perform a one step EMC lab certification…

  … a DC/DC converter can generate Conducted Emission

  … the EMC of a DC/DC converter is affected from the PCB layout

  … with an oscilloscope you could solve some of EMI situations

DC/DC CONVERTER DESIGN CHALLENGE

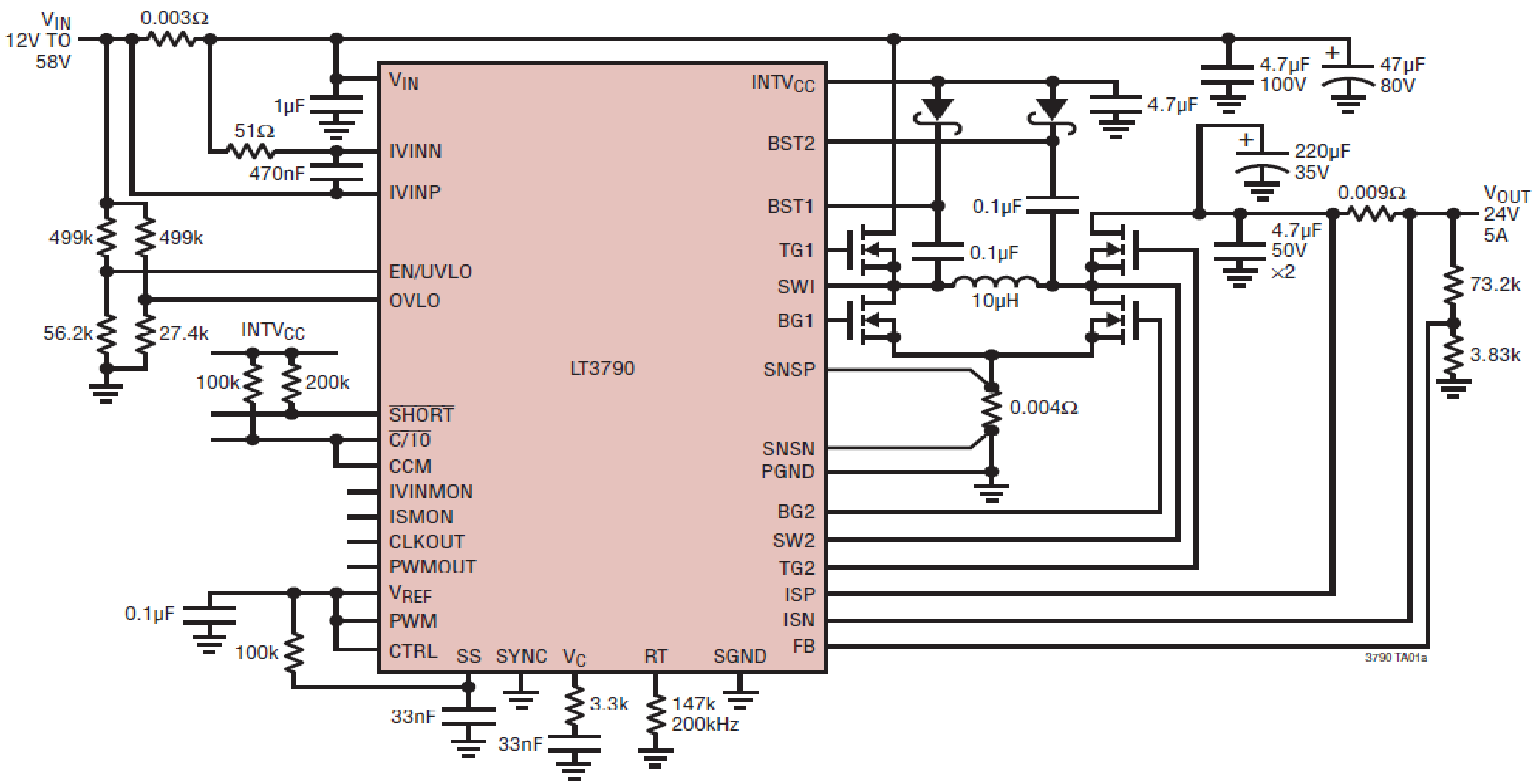
Requested:

- 100W buck-boost DC/DC
- 95% efficiency minimum
- EMC complaint for conducted and radiated
- Must fit in the already defined box
- Decision for the costs
    - lowest possible
    - Compromise for price and performance
    - No budget limit

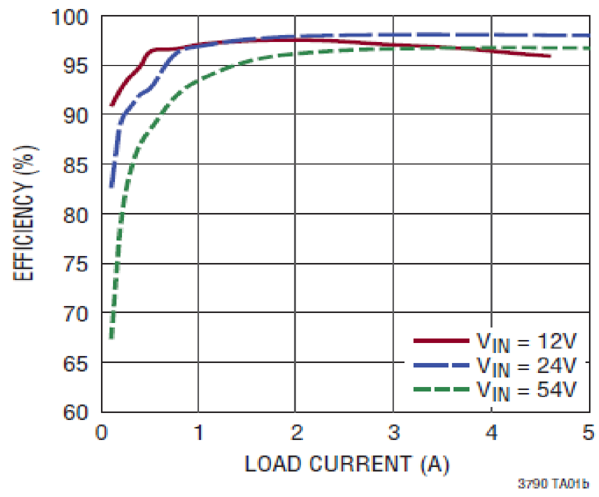
SELECTED DC/DC IC FOR NEXT EXAMPLES

- 60V Buck-Boost Controller mit 4 external MOSFETs possible switching freq. 200-700kHz

120W (24V 5A) Buck-Boost Voltage Regulator

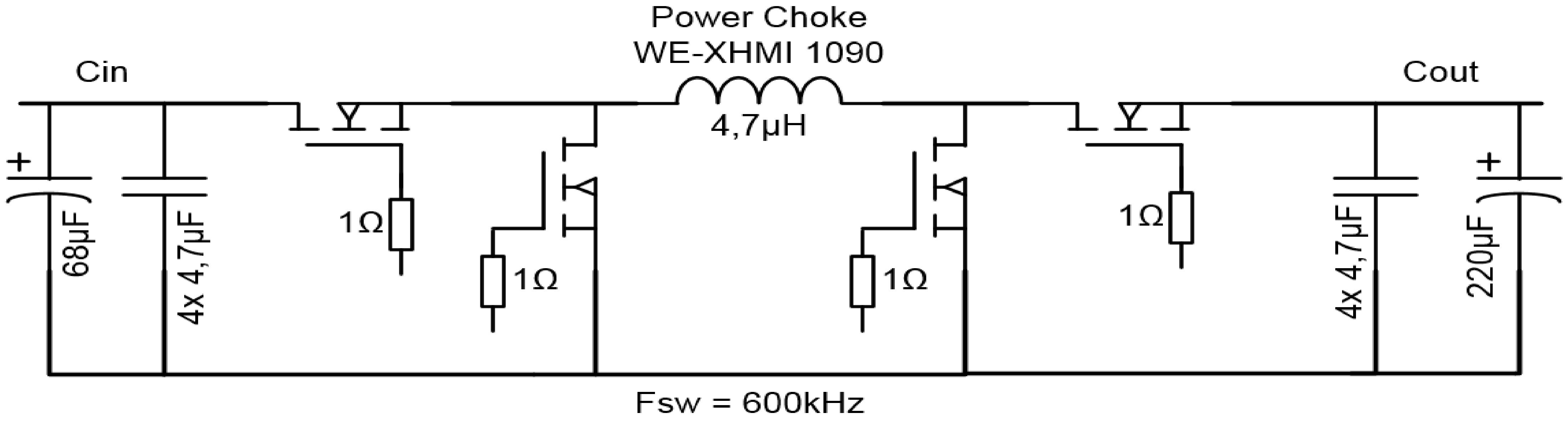


Efficiency vs Load Current



SOLUTION FOR LOWEST COST DESIGN (A)

- Single side PCB
- 4 Layer PCB
- Highest possible switching freq → 600kHz → smalest inductor can be used
- ➢ Lowest cost in comparation with the next ones

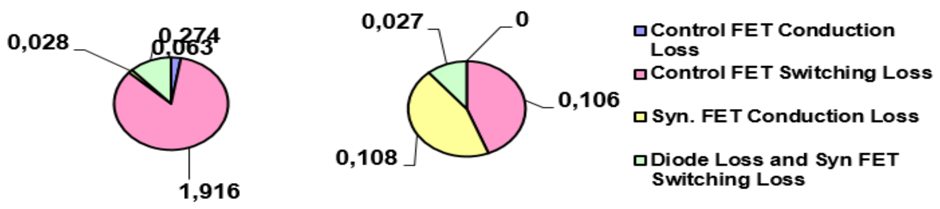


SELECTED MOSFETS FOR DESIGN (A)

- Logic Level N-Kanal FET im DPAK TO-252-3 package
- Rth not optimal
- Package ESL relativ high
- Package not compact

Estimated Power dissipation of each FET at full load, [P_{SYN}]=	0,05	0,11	W
Estimated Junction temperature, [Tj]=	50,04	50,10	°C

MOSFETs Power Loss Break Down (W)

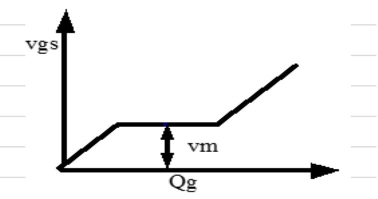


Buck Leg (A,B) Boost Leg(C,D)

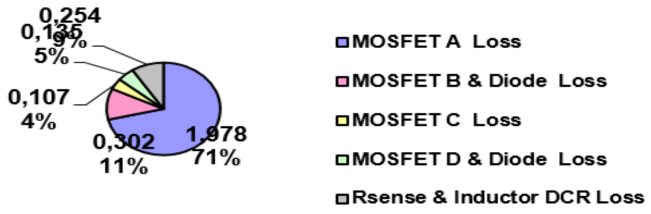
Estimated Efficiency

Overall estimated efficiency @ full load, [η]=	95,52	%

estimated.



Definition of FET Vm on Vgs Vs. Qg curve



Overall Power Loss Breakdown(W, %)

infineon **IPD031N06L3 G**

OptiMOS(TM)3 Power-Transistor

Features

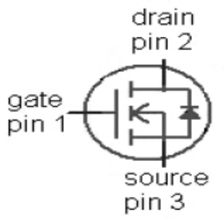
- Ideal for high frequency switching and sync. rec.
- Optimized technology for DC/DC converters
- Excellent gate charge x $R_{DS(on)}$ product (FOM)
- Very low on-resistance $R_{DS(on)}$
- N-channel, logic level
- 100% avalanche tested
- Pb-free plating; RoHS compliant
- Qualified according to JEDEC[1)] for target applications

Product Summary

V_{DS}	60	V
$R_{DS(on),max}$	3.1	mΩ
I_D	100	A

RoHS

Type	IPD031N06L3 G
	
Package	PG-TO-252-3

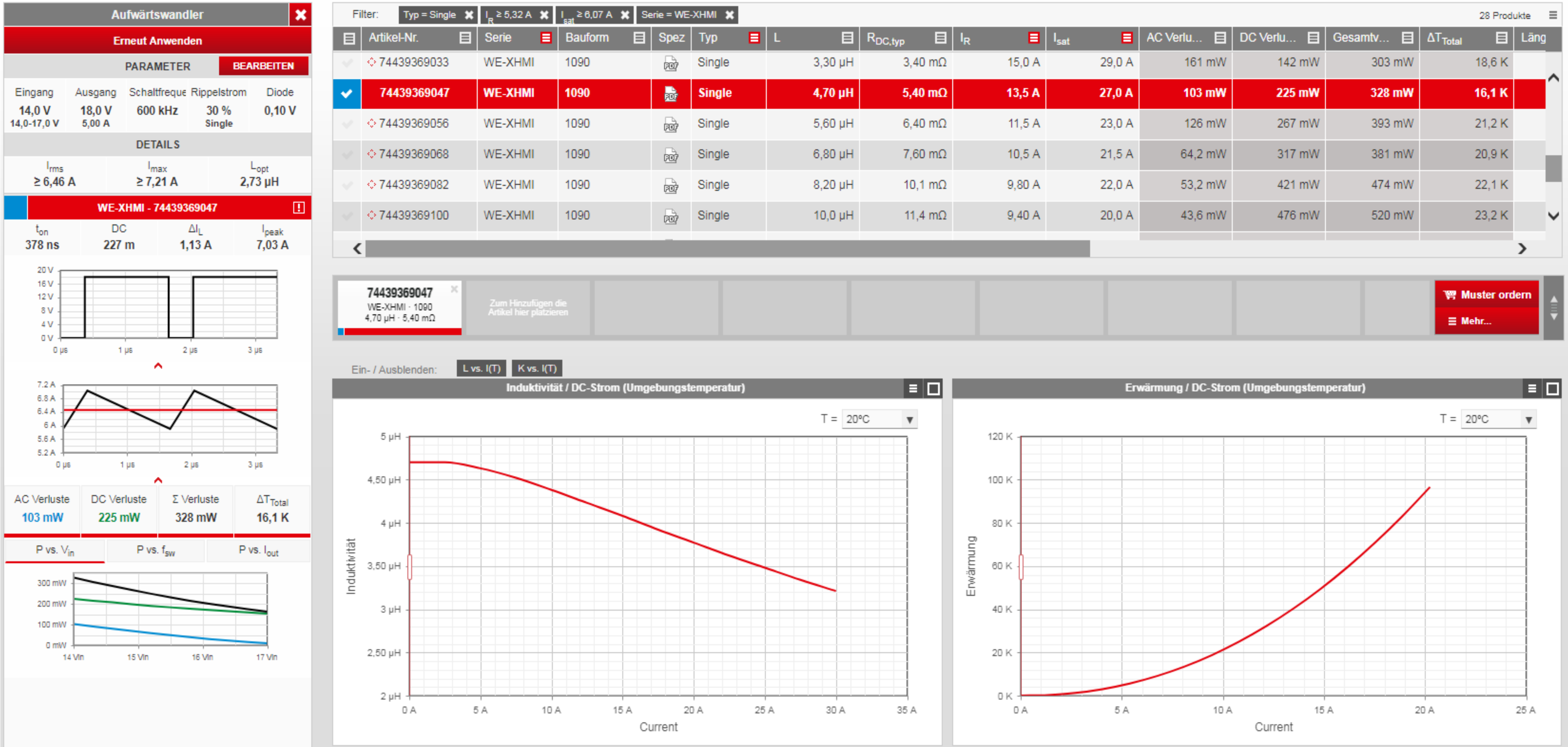


REDEXPERT: INDUCTOR SELECTION FOR DESIGN(A)

Boost Mode:

- AC loss = 0,1W
- DC loss = 0,23W
- Pv all = 0,33W
- ΔT = 16 K
- Ipeak = 7,2A

- Boost Mode →
- Selected inductor smaler (because of DutyCycle) quite high peak current!

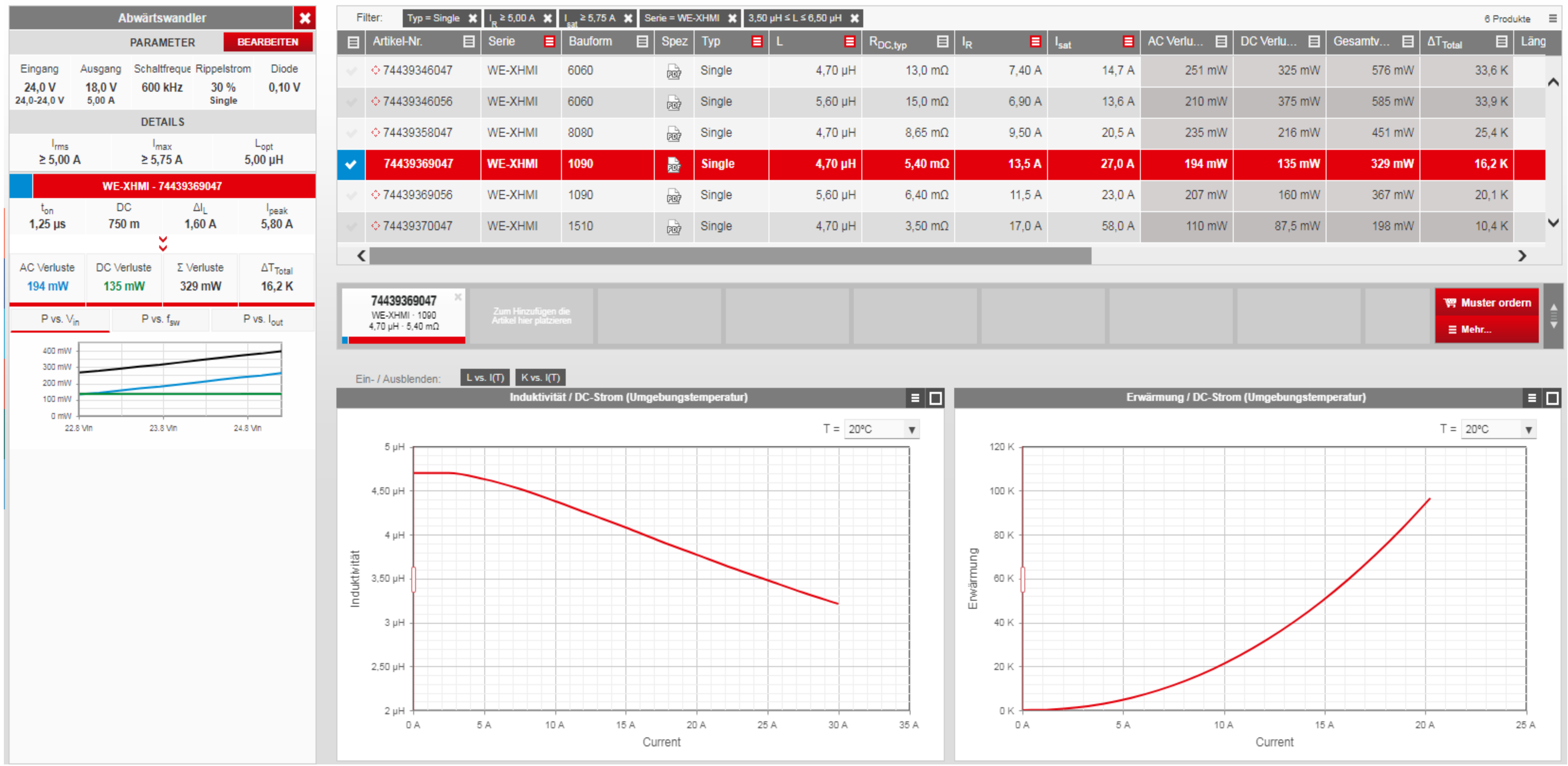


REDEXPERT: Inductor selection for Design(A)

Buck Mode:

- AC loss = 0,19W
- DC loss = 0,14W
- Pv all = 0,33W
- ΔT = 16 K
- Ipeak = 5,75A

- Buck Mode → Selected inductor bigger for smaller peak current!

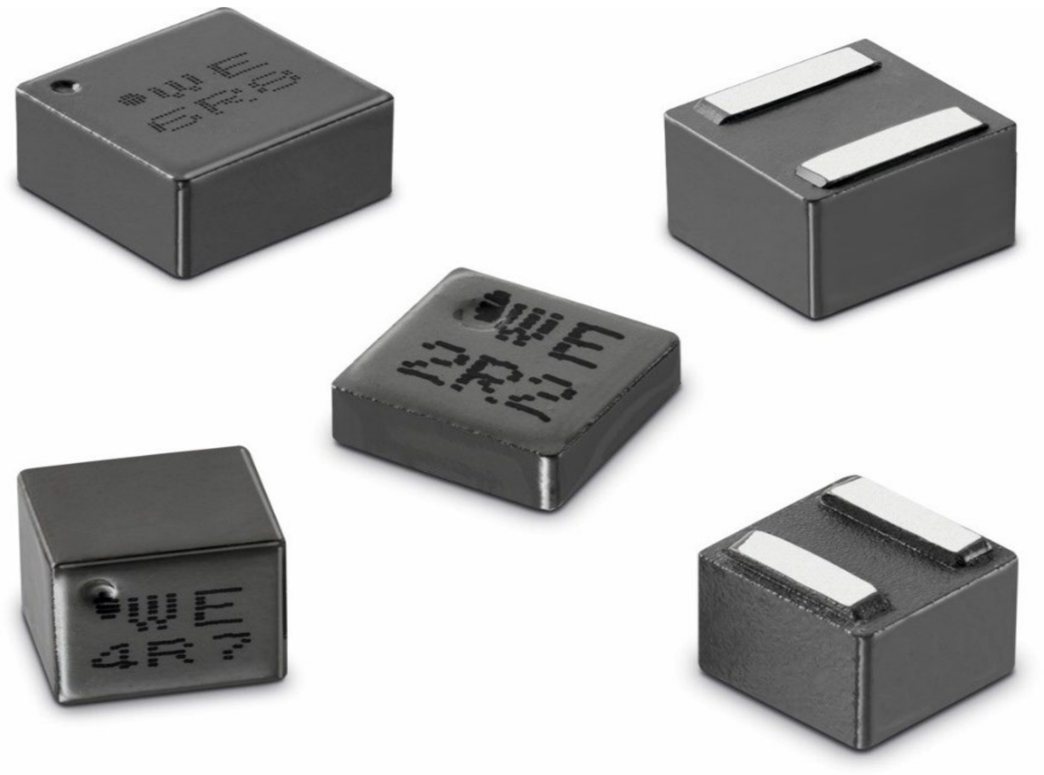


Artikel-Nr.	Serie	Bauform	Spez	Typ	L	$R_{DC,typ}$	I_R	I_{sat}	AC Verlu...	DC Verlu...	Gesamtv...	ΔT_{Total}
74439346047	WE-XHMI	6060	PDF	Single	4,70 µH	13,0 mΩ	7,40 A	14,7 A	251 mW	325 mW	576 mW	33,6 K
74439346056	WE-XHMI	6060	PDF	Single	5,60 µH	15,0 mΩ	6,90 A	13,6 A	210 mW	375 mW	585 mW	33,9 K
74439358047	WE-XHMI	8080	PDF	Single	4,70 µH	8,65 mΩ	9,50 A	20,5 A	235 mW	216 mW	451 mW	25,4 K
74439369047	WE-XHMI	1090	PDF	Single	4,70 µH	5,40 mΩ	13,5 A	27,0 A	194 mW	135 mW	329 mW	16,2 K
74439369056	WE-XHMI	1090	PDF	Single	5,60 µH	6,40 mΩ	11,5 A	23,0 A	207 mW	160 mW	367 mW	20,1 K
74439370047	WE-XHMI	1510	PDF	Single	4,70 µH	3,50 mΩ	17,0 A	58,0 A	110 mW	87,5 mW	198 mW	10,4 K

REDEXPERT: INDUCTOR SELECTION FOR DESIGN(A)

- Fsw 600kHz → 30% max. Ripple current → Inductor 4,7µH

- Selected by REDEXPERT
- Type of inductor : WE-XHMI
  - Flat wire and shielded
  - Size 1090 (10x10x9mm)
  - Nominal current : 13,5A
  - Saturation current : 27A
  - Rdc : 5,4mΩ



REDEXPERT: INPUT CAP SELECTION FOR DESIGN(A)

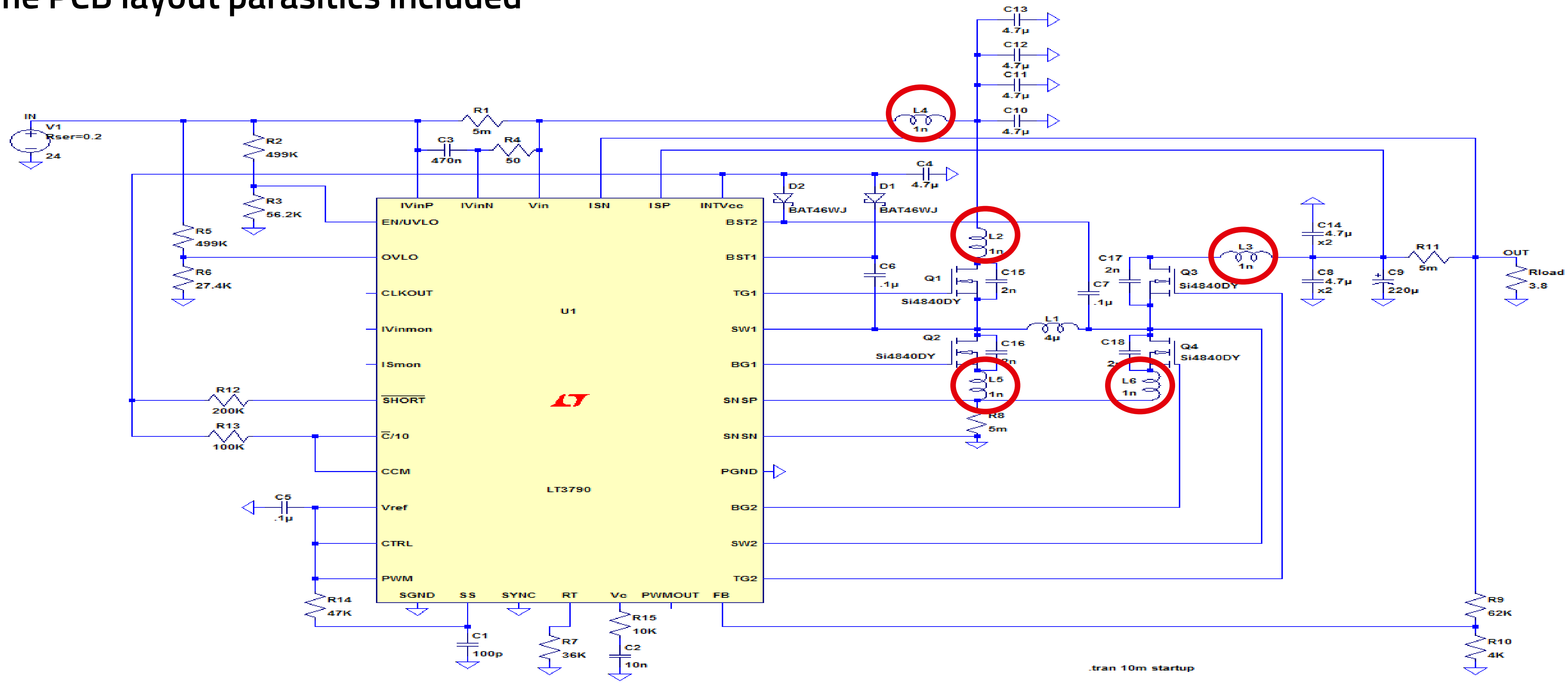
- Calculation for Cin MLCC X7R for maximum allowed ripple current

$$C_{in} \geq \frac{D \times (1 - D) \times I_{outmax}}{\Delta V_{in\,pp} \times f_{sw}} \qquad C_{in} \geq \frac{0{,}78 \times (1 - 0{,}78) \times 5A}{100mVpp \times 600kHz} = 14\mu F$$

Artikel-Nr.	Serie	Bauform	Spez	Typ	Artikelb...	C	U_R	R_{iso}	ESR @6...	$\Delta C(V_{DC}$-...	DF	Q	Länge	Breite	Höhe	T_{max}	Montage
885012209048	WCAP-CS...	1210	PDF	X7R	X7R12104...	4,70 µF	50,0 V	> 20,0 MΩ	2,29 mΩ	-21,9 %	5,0 %		3,20 mm	2,50 mm	1,25 mm	125°C	SMT

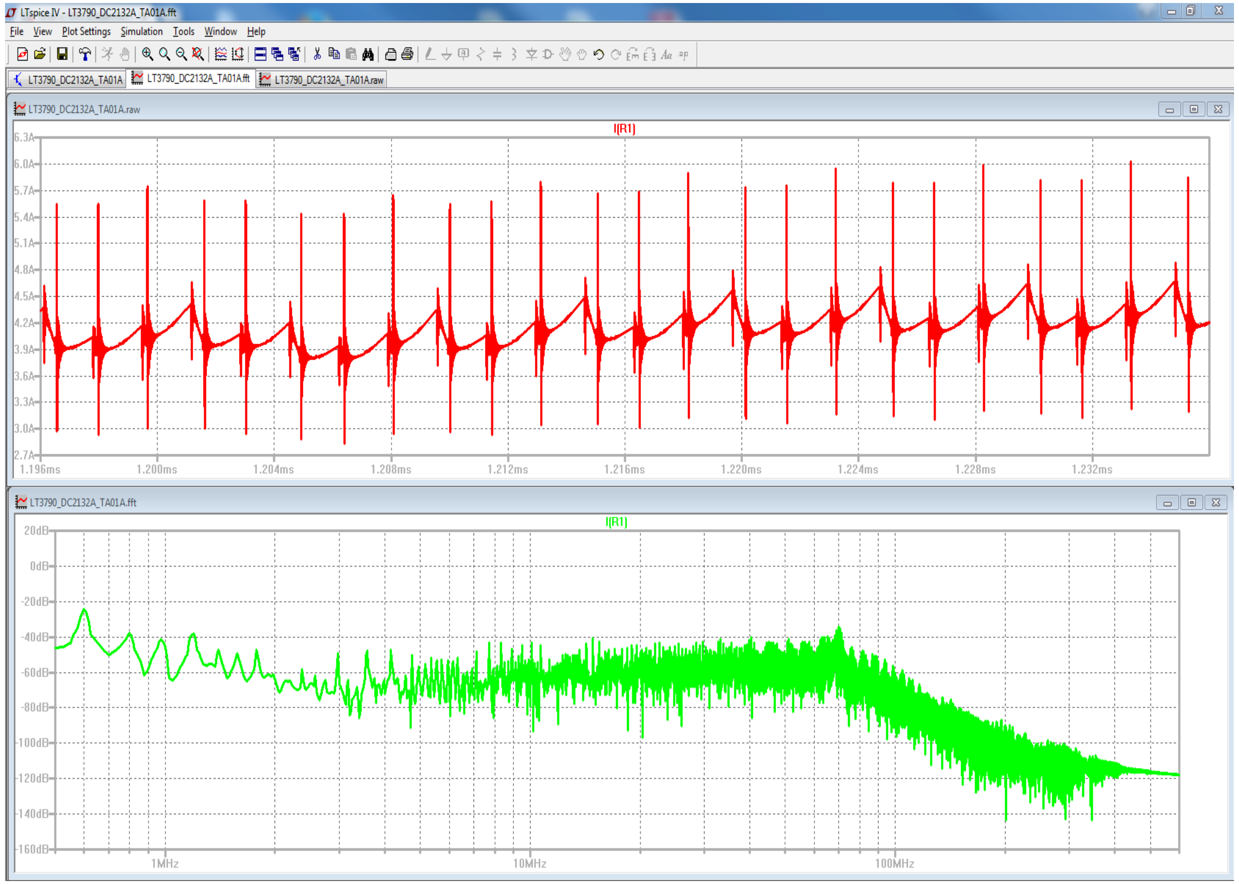
LTSPICE SIMULATION

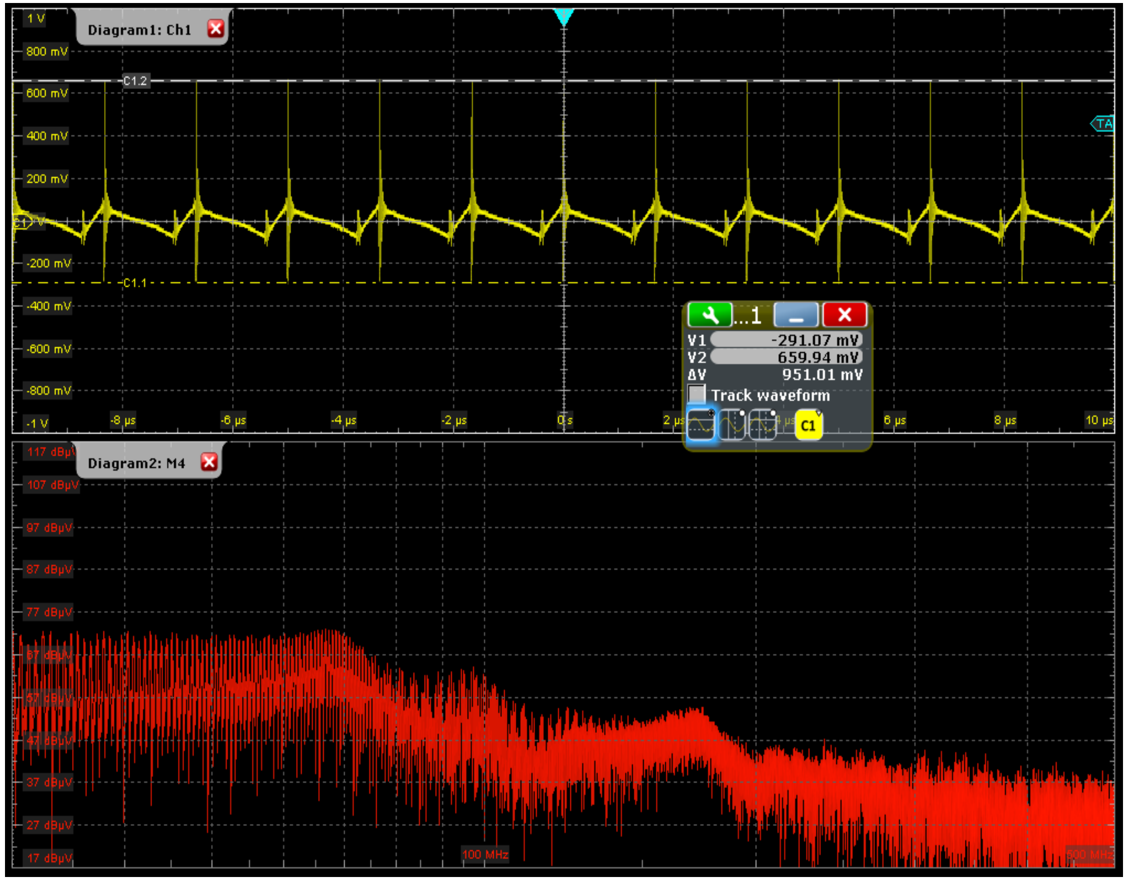
- Simulation for BuckBoost; all coponents including the parasitics
- Some PCB layout parasitics included



FILTER LTSPICE SIMULATION

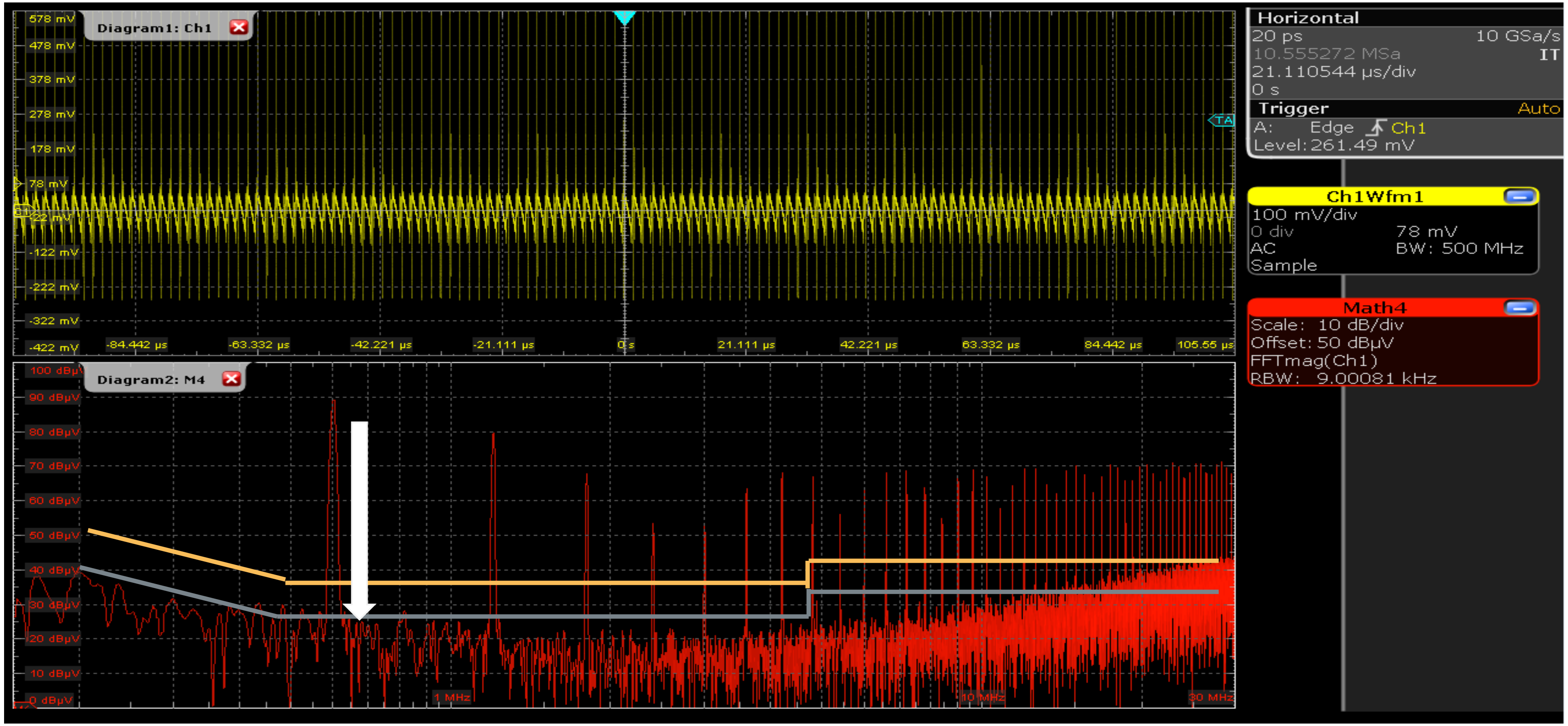
- Simulation vs. measurement





CONCLUSION FOR FILTER DESIGN

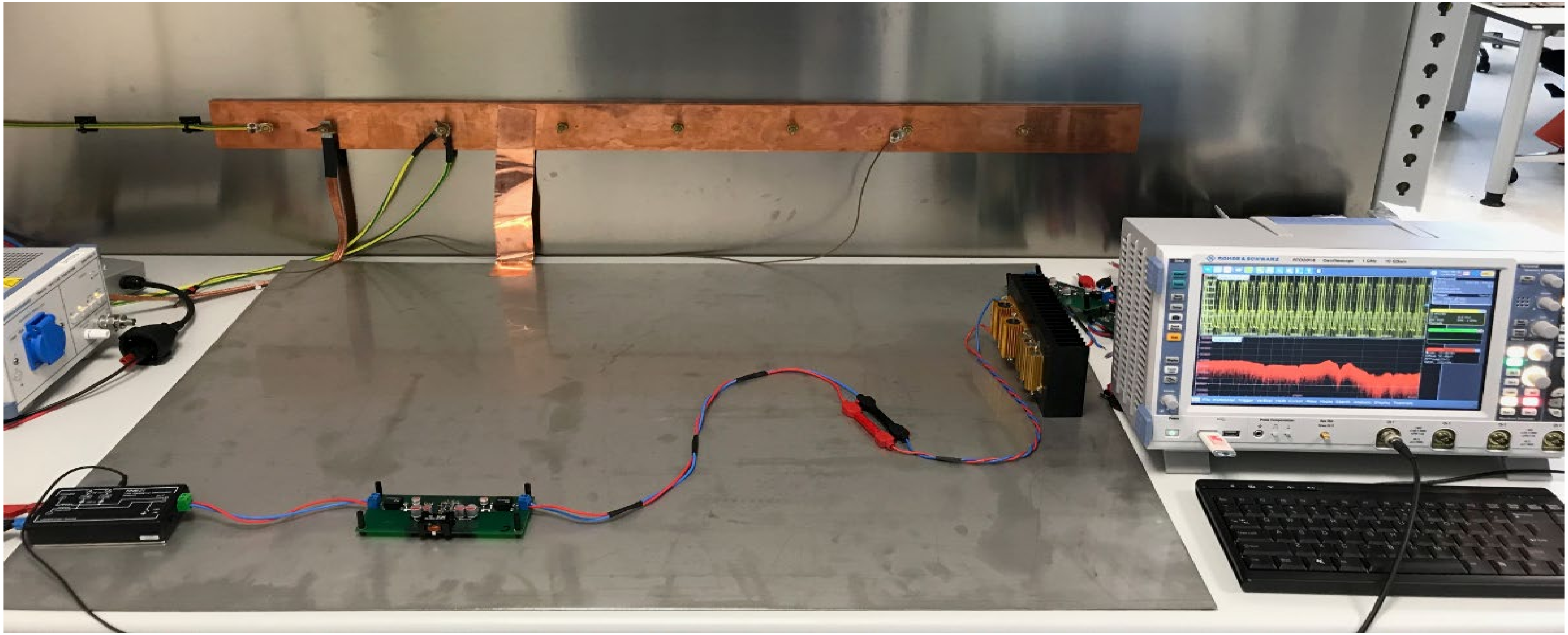
- Measurement for damping / Precompliant (ex. FFT & LISN mit 50Ω)



- Filter need to be at 600kHz ca. : 90dBµV – 40dBµV = 50dB

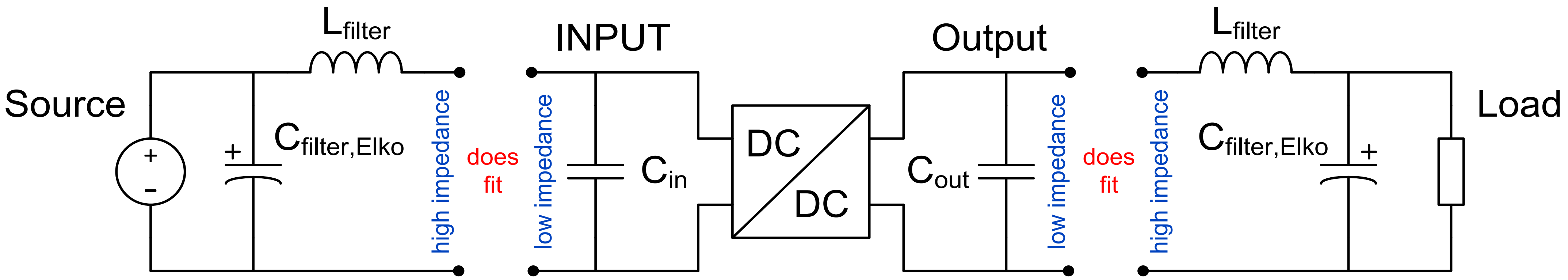
MEASUREMENT SET-UP NNB21 LISN + RTO (50Ω)

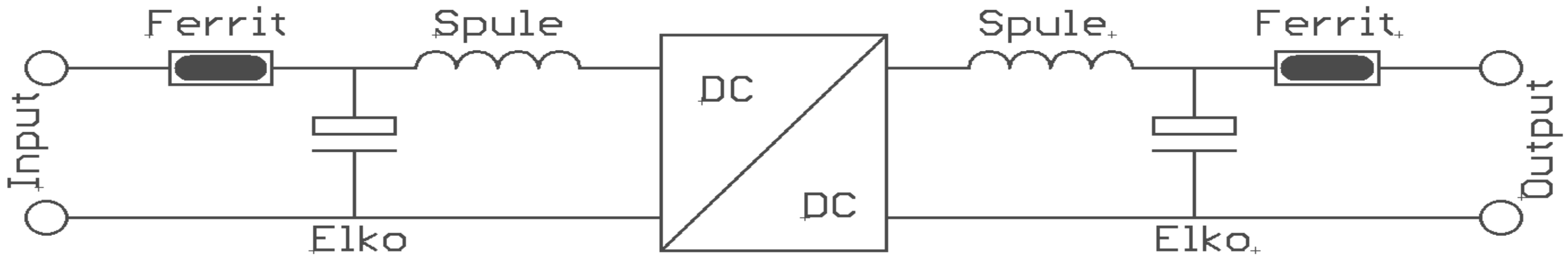
- Precompliant Measurement from 150kHz to 400MHz (in case you have a Spectrum analyzer you should use it instead of Scope)



T-FILTER FOR DESIGN (A)

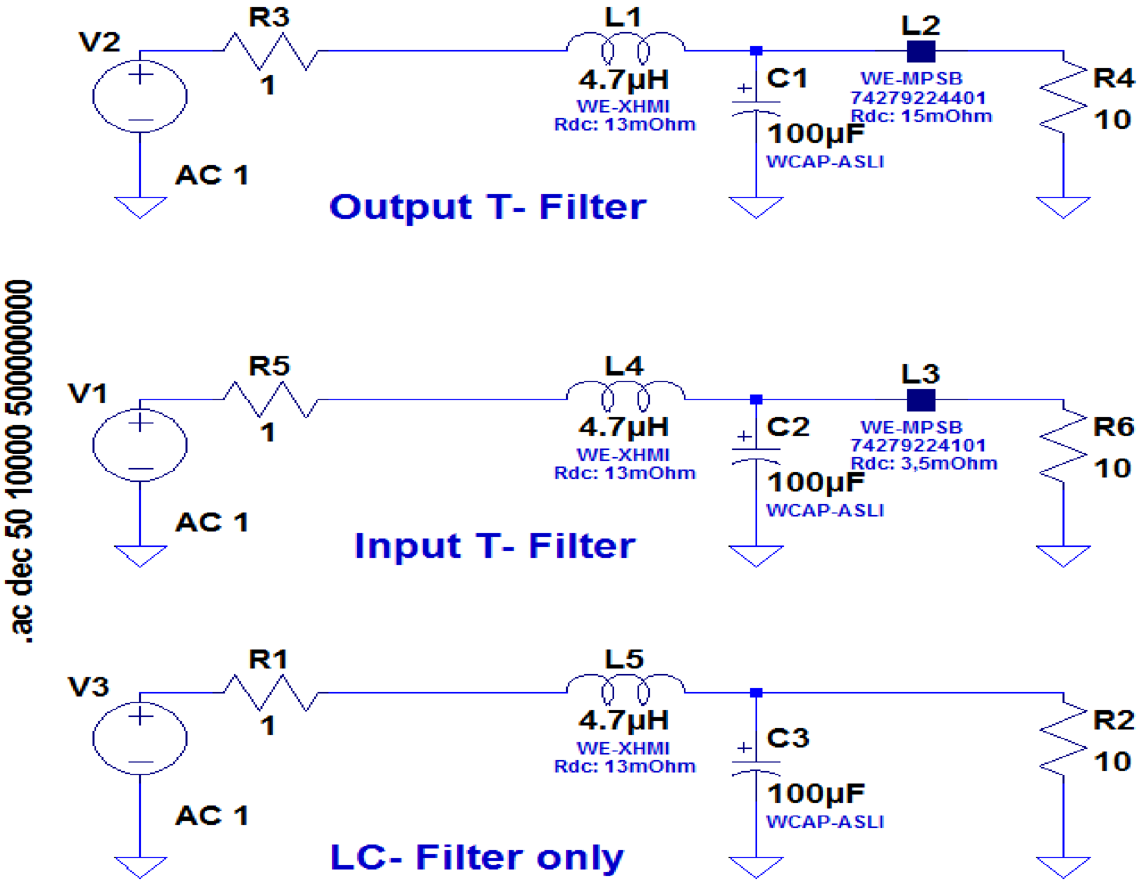
- Due to the long input wires a filter is a must
- Filter for conducted emmisions: 150kHz – 30MHz
- T – Filter can achive in theorie up to 60dB/Dec damping

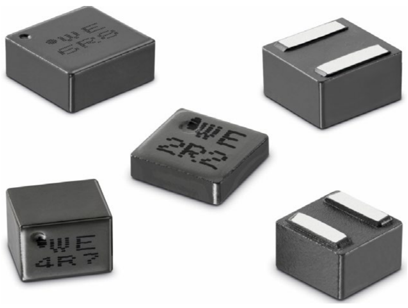


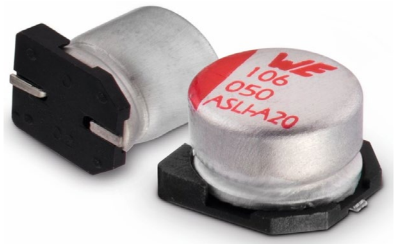


LTSPICE SIMULATION FOR T-FILTER DESIGN (A)

- All components with parasitics included
- MPSB Ferrite are suitable above ca. 5MHz

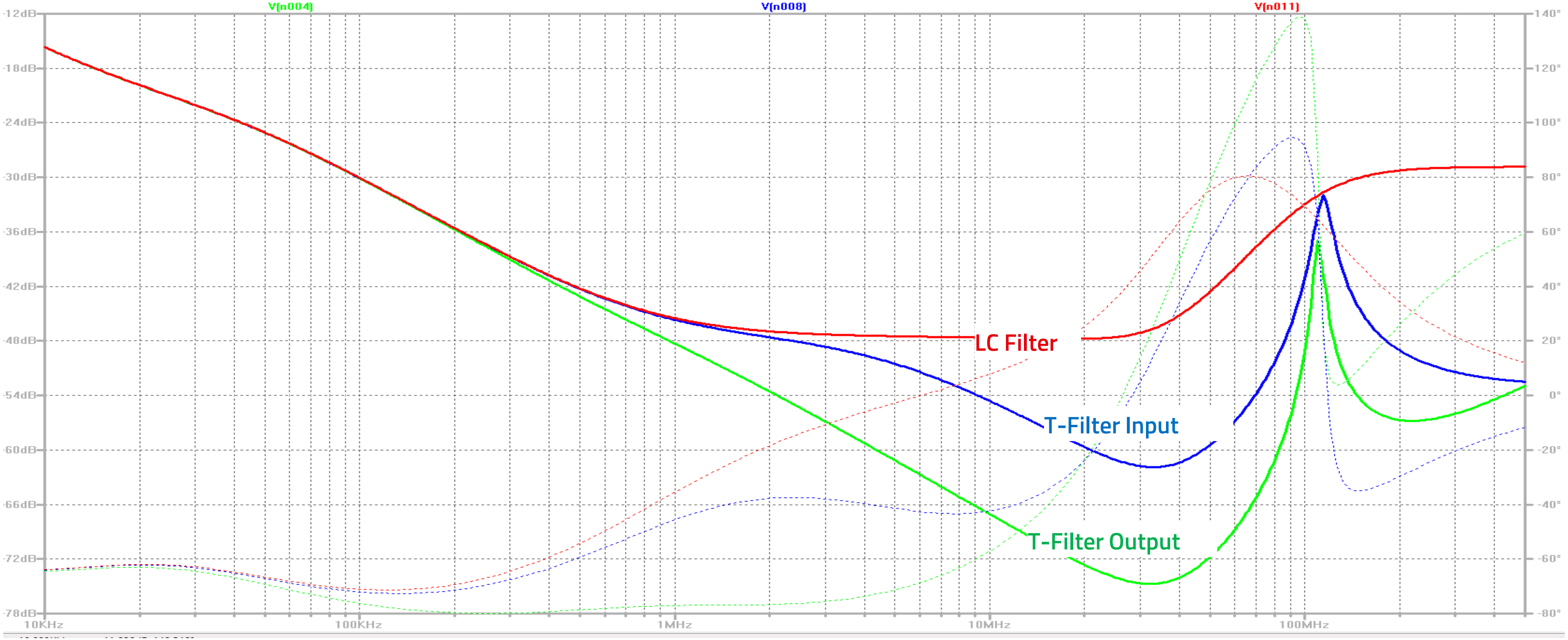






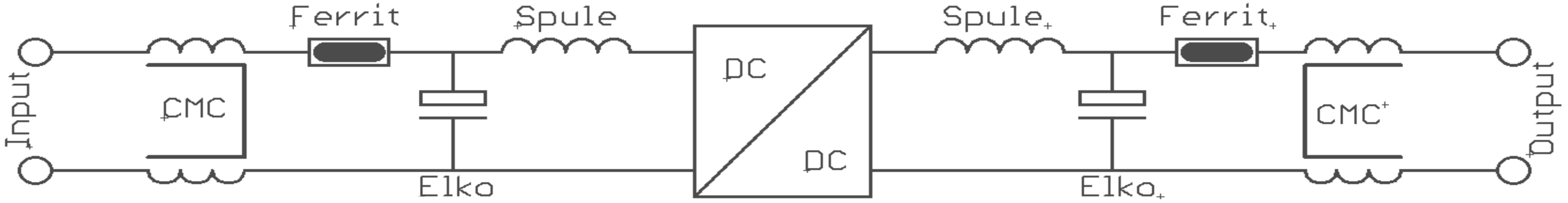
LTSPICE SIMULATION FOR T-FILTER DESIGN (A)

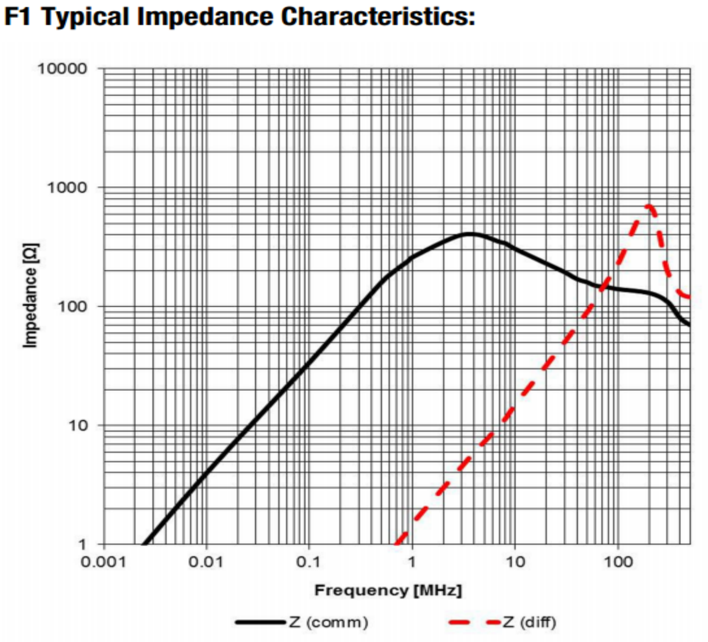
- Damping for T-Filter above 40dB Differntial Mode from 150KHz up to 80MHz



CMC FILTER FOR ALL DESIGNS

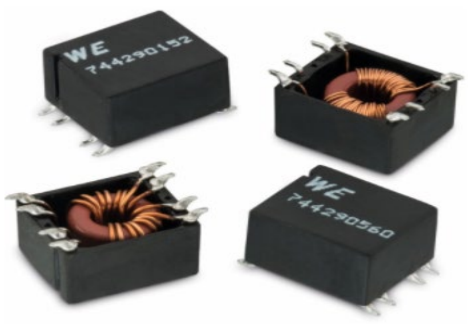
- Selected Common Mode Choke with huge bandwith for 30MHz to 500MHz
- Important to know: CMC´s are helping for imunity like BURST & HF





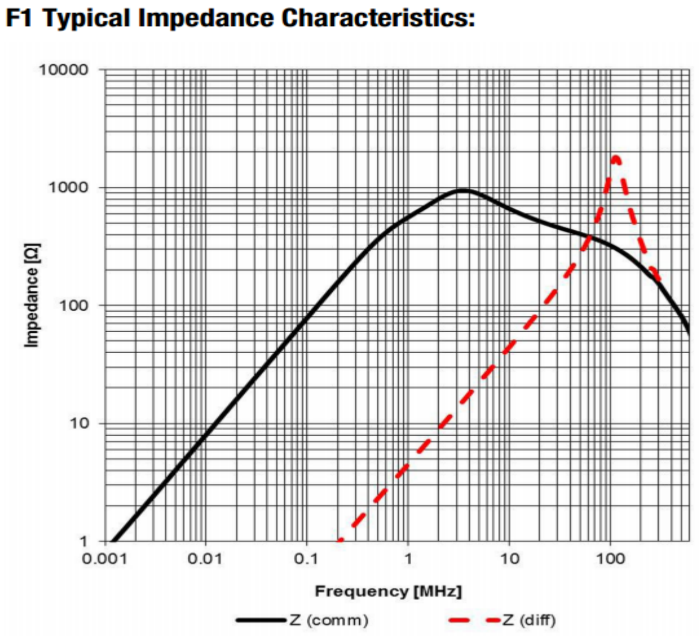
Input:

WE-UCF
2x56uH
Ir = 7A
Rdc:4,7m

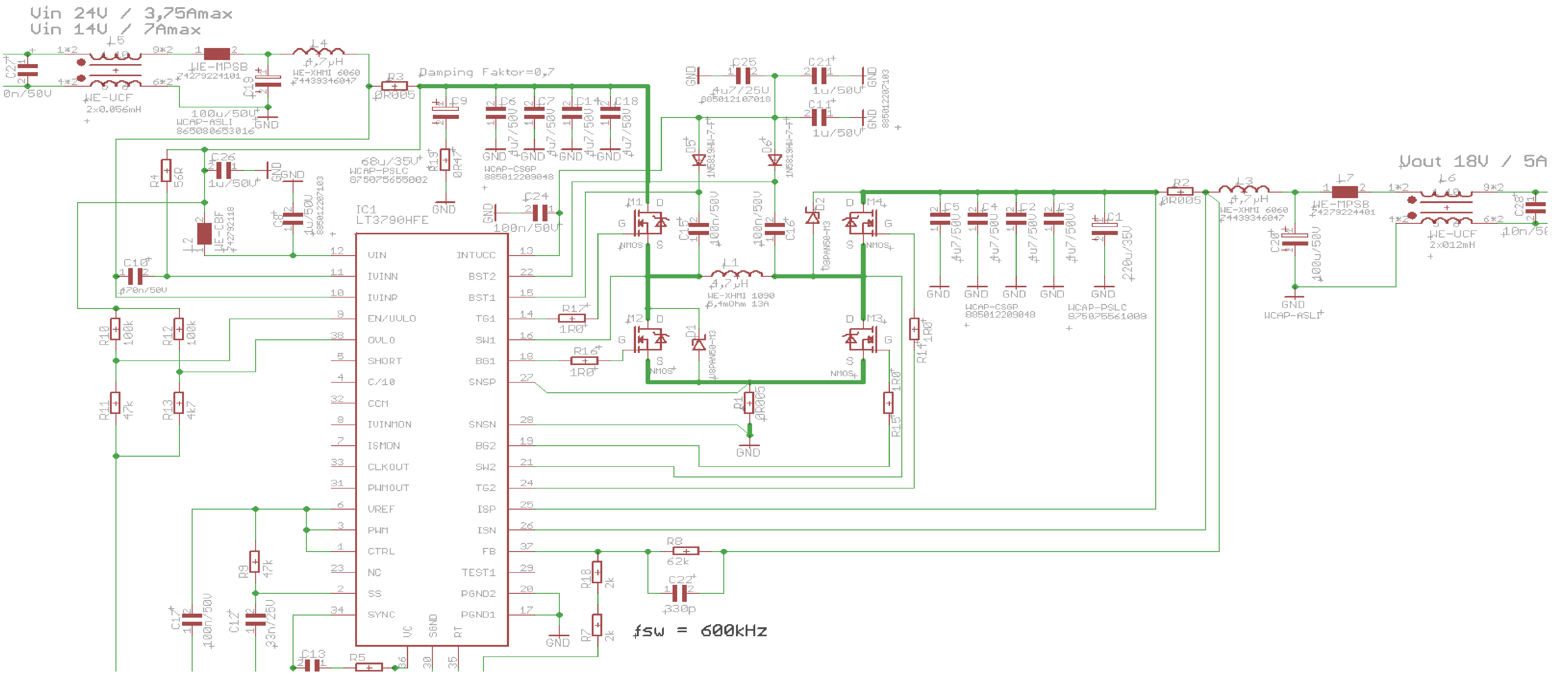


Output:

WE-UCF
2x120uH
Ir = 5,5A
Rdc:10m



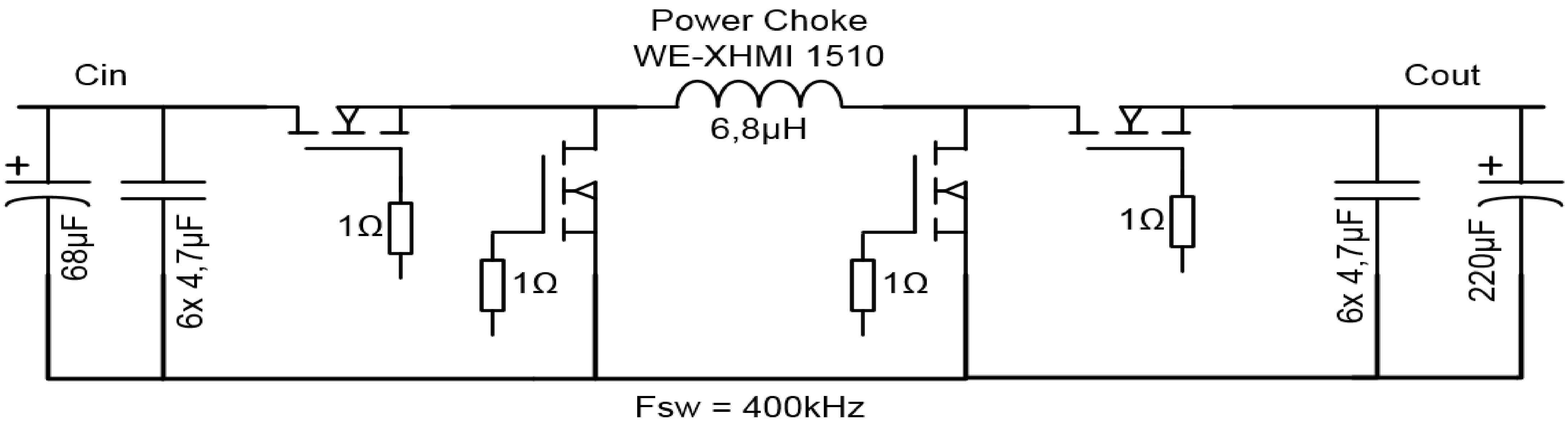
SCHEMATIC DESIGN (A)



DESIGN (B)

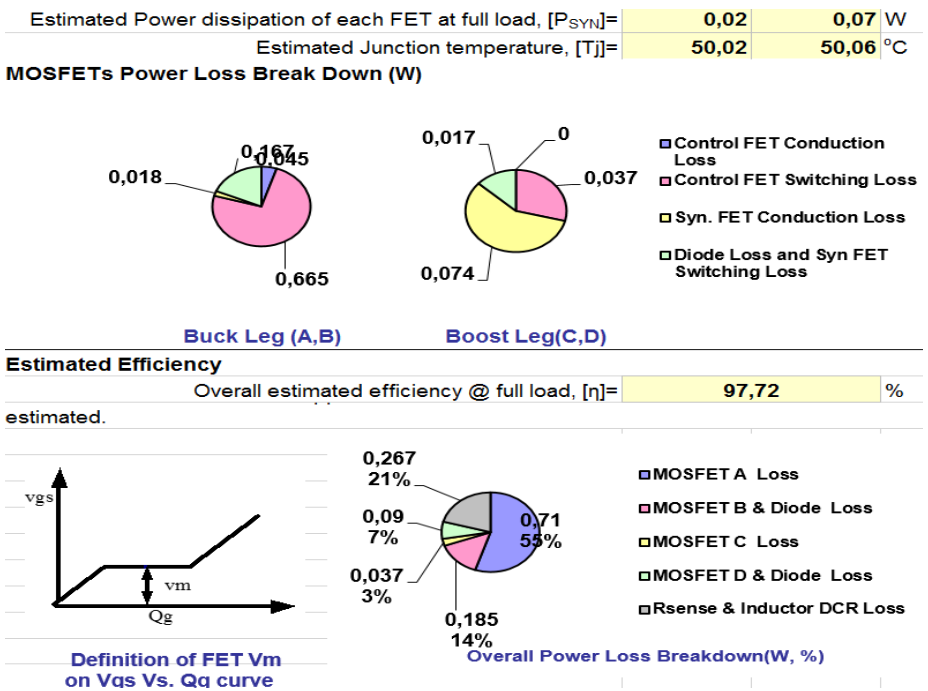
DESIGN (B)

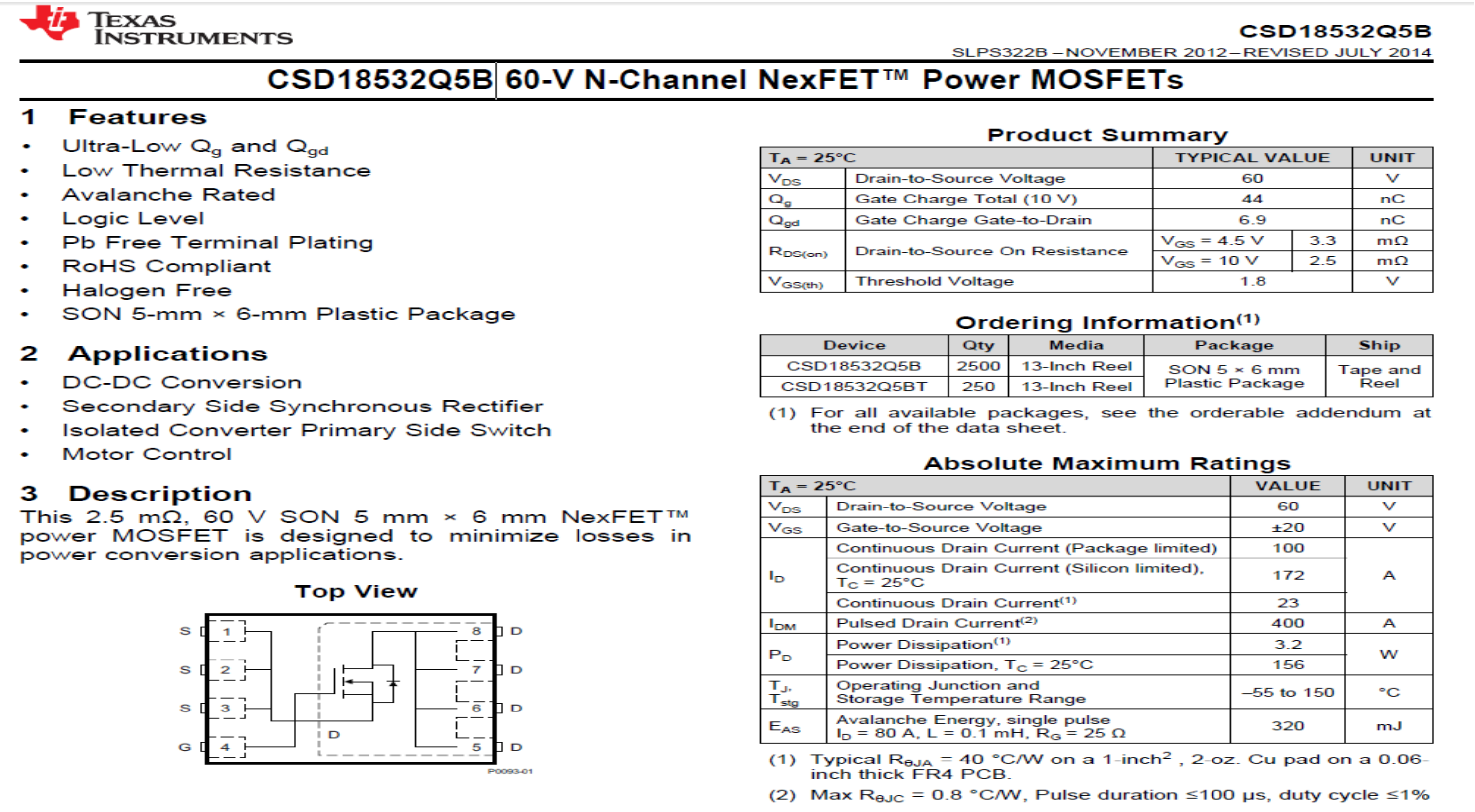
- Up and down layer using components
- 6 Layer PCB
- Moderate switching freq → 400kHz → compromise between switching losses and inductor losses
- Optimized Filter at I/O → less RDC losses
- ➢ Medium cost



MOSFETS FOR DESIGN (B)

- Logic Level N-Kanal FET in SON 5x6 package
- Rth much better
- Package ESL small
- Rdson small
- Gate Charge small





TEXAS INSTRUMENTS

CSD18532Q5B

SLPS322B – NOVEMBER 2012 – REVISED JULY 2014

CSD18532Q5B 60-V N-Channel NexFET™ Power MOSFETs

1 Features

- Ultra-Low Q_g and Q_{gd}
- Low Thermal Resistance
- Avalanche Rated
- Logic Level
- Pb Free Terminal Plating
- RoHS Compliant
- Halogen Free
- SON 5-mm × 6-mm Plastic Package

2 Applications

- DC-DC Conversion
- Secondary Side Synchronous Rectifier
- Isolated Converter Primary Side Switch
- Motor Control

3 Description

This 2.5 mΩ, 60 V SON 5 mm × 6 mm NexFET™ power MOSFET is designed to minimize losses in power conversion applications.

Top View

Product Summary

T_A = 25°C		TYPICAL VALUE		UNIT
V_{DS}	Drain-to-Source Voltage	60		V
Q_g	Gate Charge Total (10 V)	44		nC
Q_{gd}	Gate Charge Gate-to-Drain	6.9		nC
$R_{DS(on)}$	Drain-to-Source On Resistance	V_{GS} = 4.5 V	3.3	mΩ
		V_{GS} = 10 V	2.5	mΩ
$V_{GS(th)}$	Threshold Voltage	1.8		V

Ordering Information(1)

Device	Qty	Media	Package	Ship
CSD18532Q5B	2500	13-Inch Reel	SON 5 × 6 mm Plastic Package	Tape and Reel
CSD18532Q5BT	250	13-Inch Reel		

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Absolute Maximum Ratings

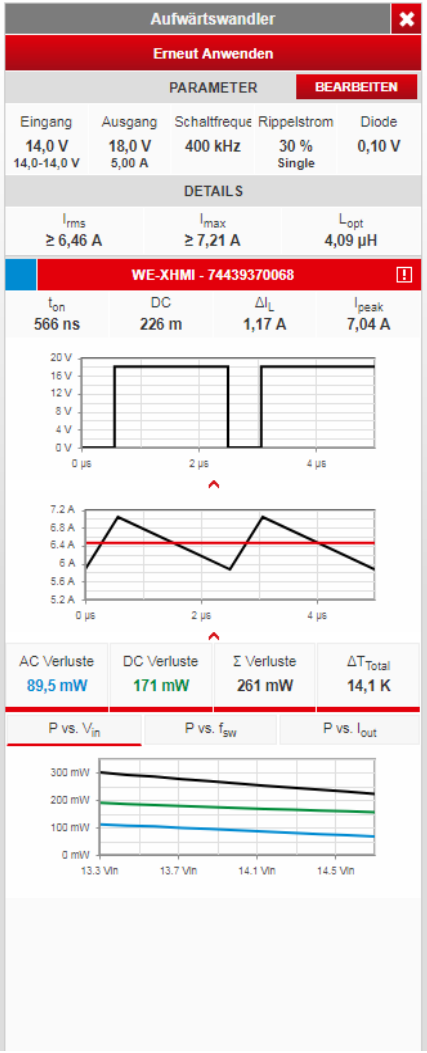
T_A = 25°C		VALUE	UNIT
V_{DS}	Drain-to-Source Voltage	60	V
V_{GS}	Gate-to-Source Voltage	±20	V
I_D	Continuous Drain Current (Package limited)	100	A
	Continuous Drain Current (Silicon limited), T_C = 25°C	172	
	Continuous Drain Current(1)	23	
I_{DM}	Pulsed Drain Current(2)	400	A
P_D	Power Dissipation(1)	3.2	W
	Power Dissipation, T_C = 25°C	156	
T_J, T_{stg}	Operating Junction and Storage Temperature Range	–55 to 150	°C
E_{AS}	Avalanche Energy, single pulse I_D = 80 A, L = 0.1 mH, R_G = 25 Ω	320	mJ

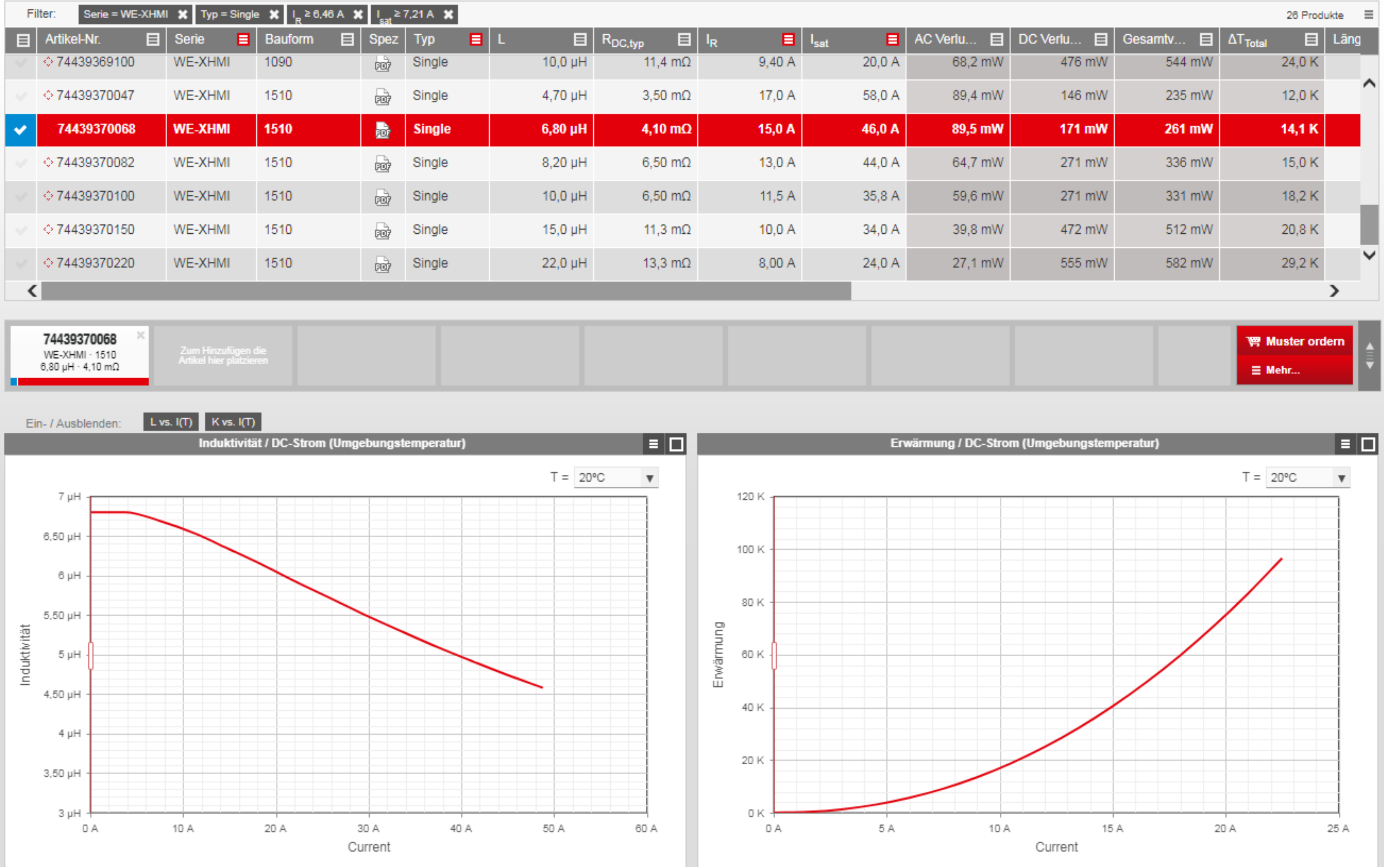
(1) Typical $R_{\theta JA}$ = 40 °C/W on a 1-inch², 2-oz. Cu pad on a 0.06-inch thick FR4 PCB.
(2) Max $R_{\theta JC}$ = 0.8 °C/W, Pulse duration ≤100 μs, duty cycle ≤1%

REDEXPERT: INDUCTOR SELECTION FOR DESIGN (B)

Boost Mode:

- AC loss = 0,09W
- DC loss = 0,17W
- Pv all = 0,26W
- ΔT = 14K
- Ipeak = 7,2A



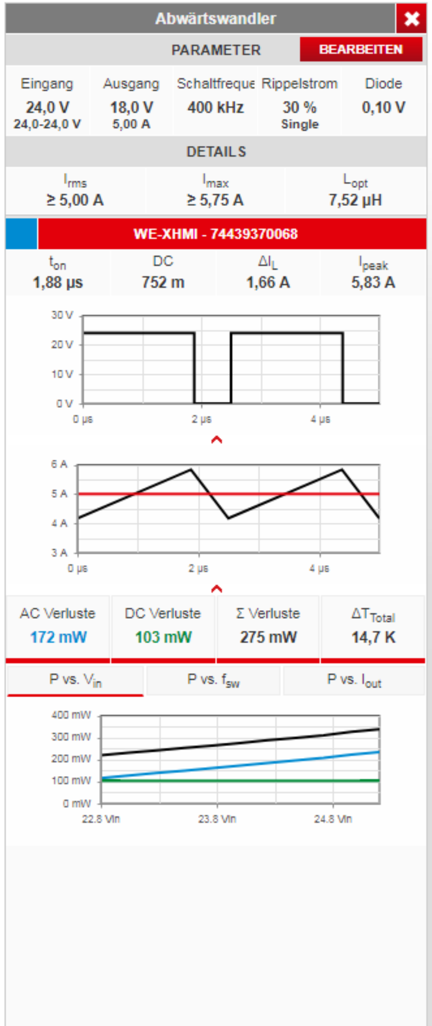


Artikel-Nr.	Serie	Bauform	Spez	Typ	L	$R_{DC,typ}$	I_R	I_{sat}	AC Verlu...	DC Verlu...	Gesamtv...	ΔT_{Total}
74439369100	WE-XHMI	1090	PDF	Single	10,0 µH	11,4 mΩ	9,40 A	20,0 A	68,2 mW	476 mW	544 mW	24,0 K
74439370047	WE-XHMI	1510	PDF	Single	4,70 µH	3,50 mΩ	17,0 A	58,0 A	89,4 mW	146 mW	235 mW	12,0 K
74439370068	WE-XHMI	1510	PDF	Single	6,80 µH	4,10 mΩ	15,0 A	46,0 A	89,5 mW	171 mW	261 mW	14,1 K
74439370082	WE-XHMI	1510	PDF	Single	8,20 µH	6,50 mΩ	13,0 A	44,0 A	64,7 mW	271 mW	336 mW	15,0 K
74439370100	WE-XHMI	1510	PDF	Single	10,0 µH	6,50 mΩ	11,5 A	35,8 A	59,6 mW	271 mW	331 mW	18,2 K
74439370150	WE-XHMI	1510	PDF	Single	15,0 µH	11,3 mΩ	10,0 A	34,0 A	39,8 mW	472 mW	512 mW	20,8 K
74439370220	WE-XHMI	1510	PDF	Single	22,0 µH	13,3 mΩ	8,00 A	24,0 A	27,1 mW	555 mW	582 mW	29,2 K

REDEXPERT: INDUCTOR SELECTION FOR DESIGN (B)

Buck Mode:

- AC loss = 0,17W
- DC loss = 0,1W
- Pv all = 0,27W
- ΔT = 14,7 K
- Ipeak = 5,75A

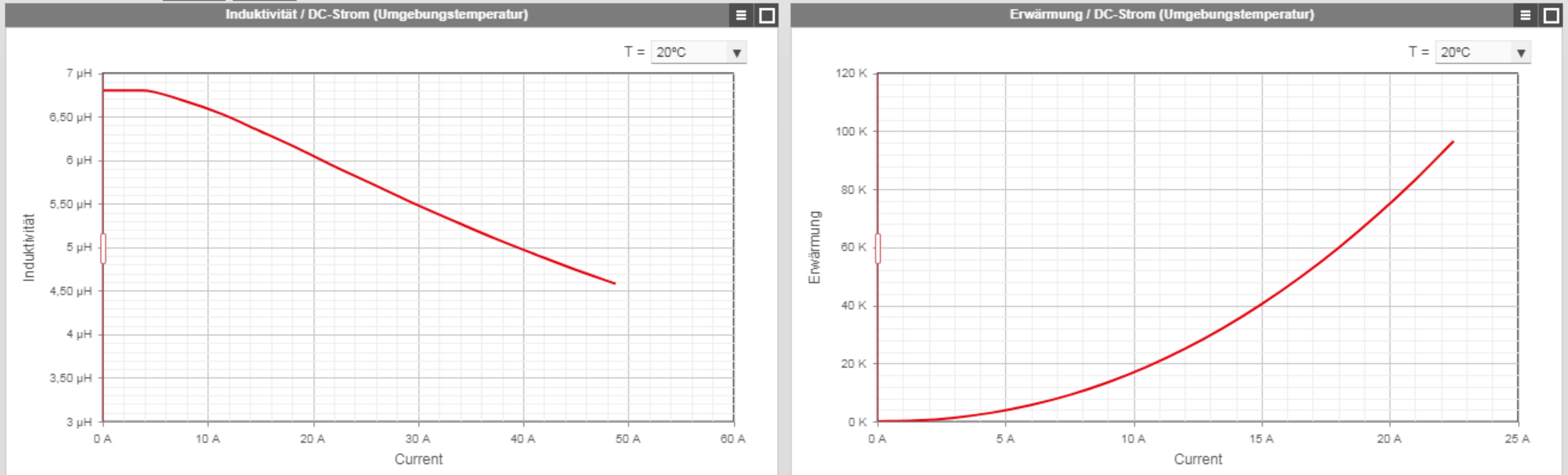


Filter: Serie = WE-XHMI | Typ = Single | I_R ≥ 5,00 A | I_{sat} ≥ 5,75 A | 5,26 µH ≤ L ≤ 9,78 µH — 9 Produkte

Artikel-Nr.	Serie	Bauform	Spez	Typ	L	$R_{DC,typ}$	I_R	I_{sat}	AC Verlu...	DC Verlu...	Gesamtv...	ΔT_{Total}
74439346082	WE-XHMI	6060	PDF	Single	8,20 µH	23,0 mΩ	5,30 A	8,40 A	226 mW	575 mW	801 mW	47,8 K
74439358068	WE-XHMI	8080	PDF	Single	6,80 µH	13,5 mΩ	7,20 A	15,0 A	213 mW	338 mW	551 mW	32,8 K
74439369056	WE-XHMI	1090	PDF	Single	5,60 µH	6,40 mΩ	11,5 A	23,0 A	303 mW	160 mW	463 mW	24,3 K
74439369068	WE-XHMI	1090	PDF	Single	6,80 µH	7,60 mΩ	10,5 A	21,5 A	191 mW	190 mW	381 mW	20,9 K
74439369082	WE-XHMI	1090	PDF	Single	8,20 µH	10,1 mΩ	9,80 A	22,0 A	158 mW	253 mW	411 mW	19,7 K
74439370068	**WE-XHMI**	**1510**	PDF	**Single**	**6,80 µH**	**4,10 mΩ**	**15,0 A**	**46,0 A**	**172 mW**	**103 mW**	**275 mW**	**14,7 K**
74439370082	WE-XHMI	1510	PDF	Single	8,20 µH	6,50 mΩ	13,0 A	44,0 A	143 mW	163 mW	306 mW	13,9 K

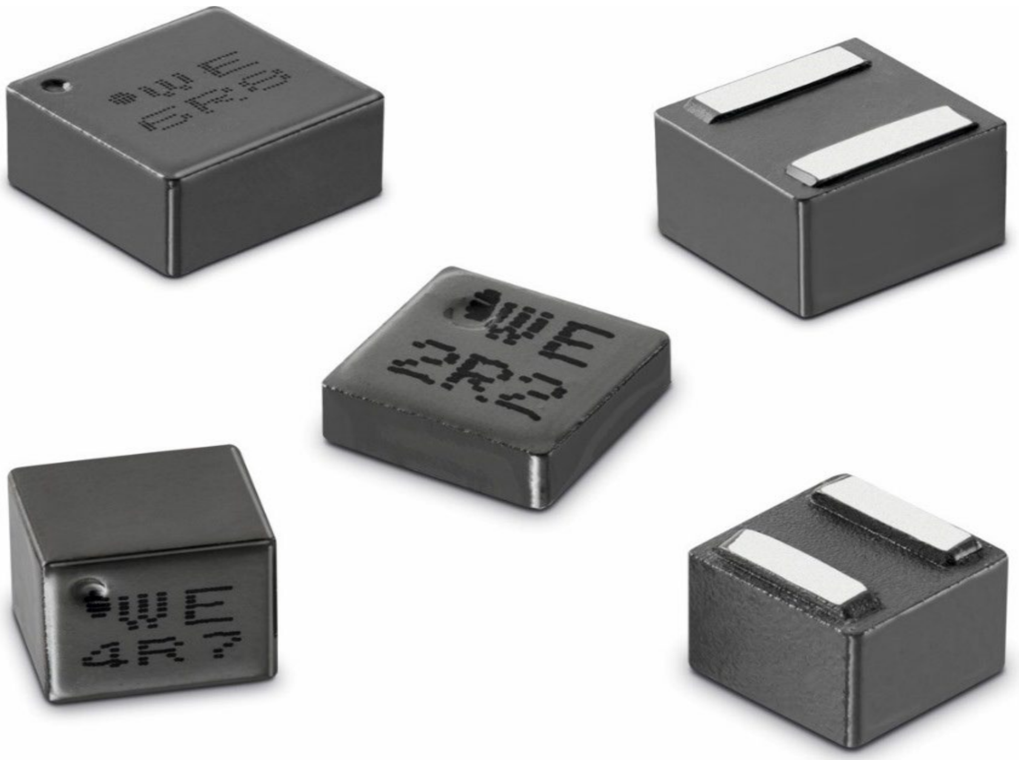
74439370068 WE-XHMI · 1510 6,80 µH · 4,10 mΩ — Muster ordern — Mehr...

Ein- / Ausblenden: L vs. I(T) | K vs. I(T)



INDUCTOR SELECTION FOR DESIGN (B)

- Fsw 400kHz → 30% max. ripple current → Inductor ca. 6,8µH
- Selection with REDEXPERT
- Type of inductor: WE-XHMI
  - Flat wire and shielded
  - Size 1510 (15x15x10mm)
  - Nominal current : 15A
  - Saturation curent : 46A
  - Rdc : 4,1mΩ

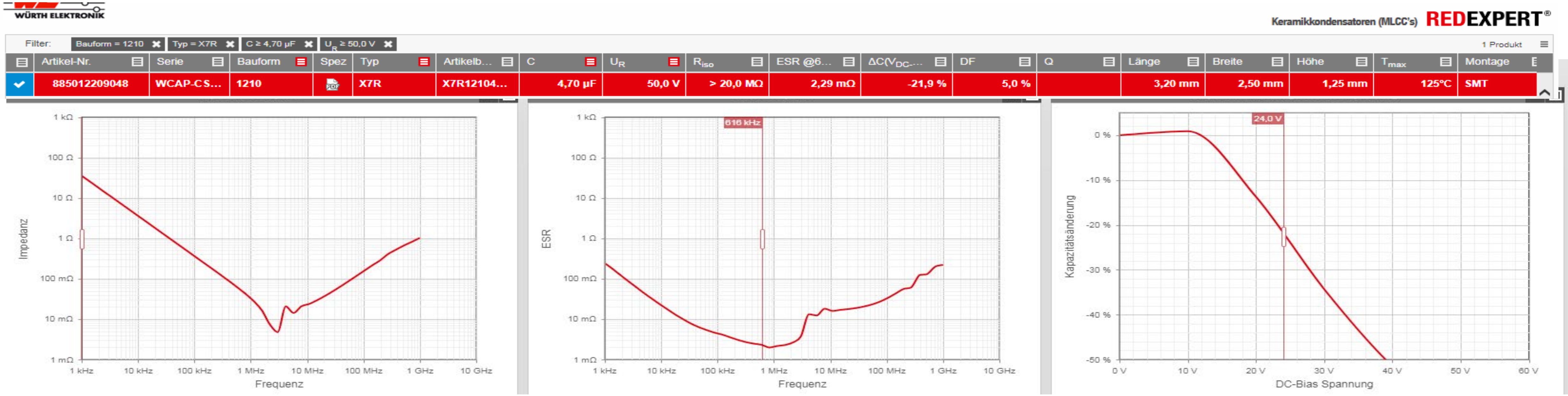


INPUT CAPACITOR CALCULATION FOR DESIGN (B)

- **Cin used MLCC X7R for max allowed ripple voltage**

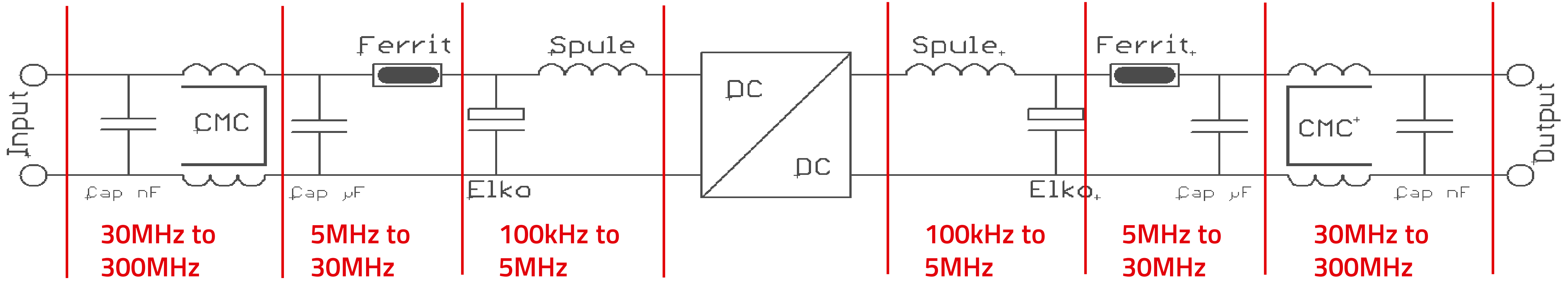
$$C_{in} \geq \frac{D \times (1 - D) \times I_{outmax}}{\Delta V_{in\,pp} \times f_{sw}} \qquad C_{in} \geq \frac{0{,}78 \times (1 - 0{,}78) \times 5{,}5A}{100mVpp \times 400kHz} = 21\mu F$$

➢ Selected : 6 x 4,7µF / 50V / X7R = 28,2µF – 20% DC-Bias = 23µF



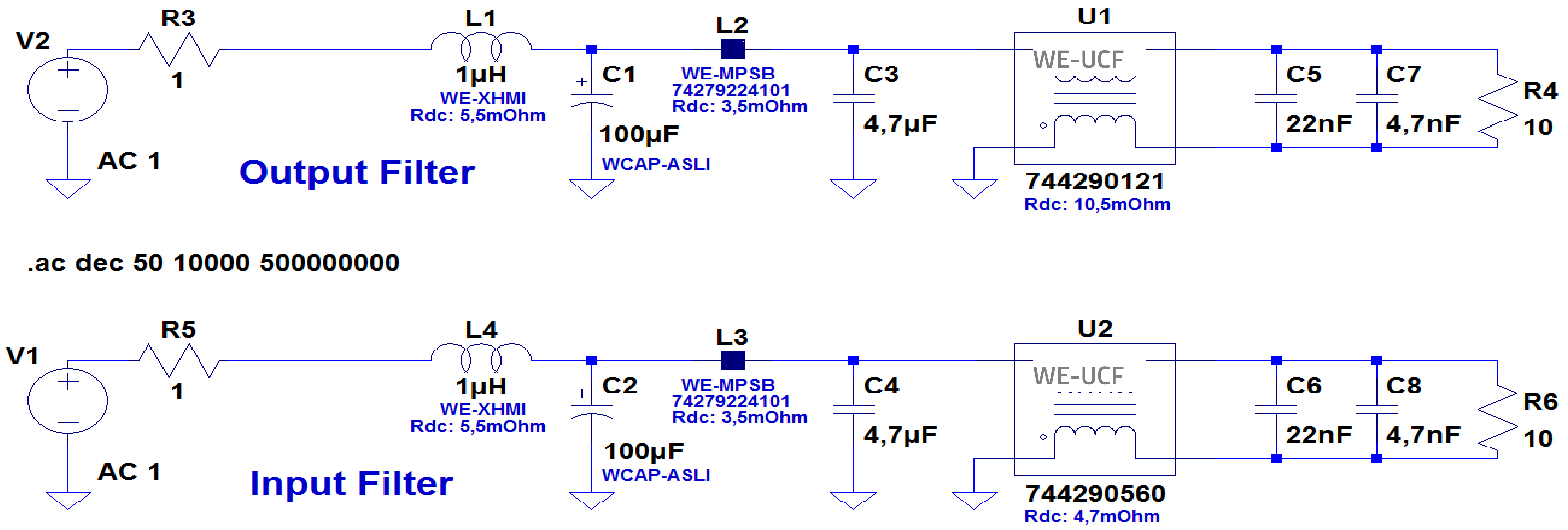
FILTER OPTIMIZATION FOR DIFF MODE FOR DESIGN (B)

- Filter for Conducted und Radiated Emission Test Spectrum
- 3 filter stage's
- At the CMC will only the leackage inductor for diff mode considered

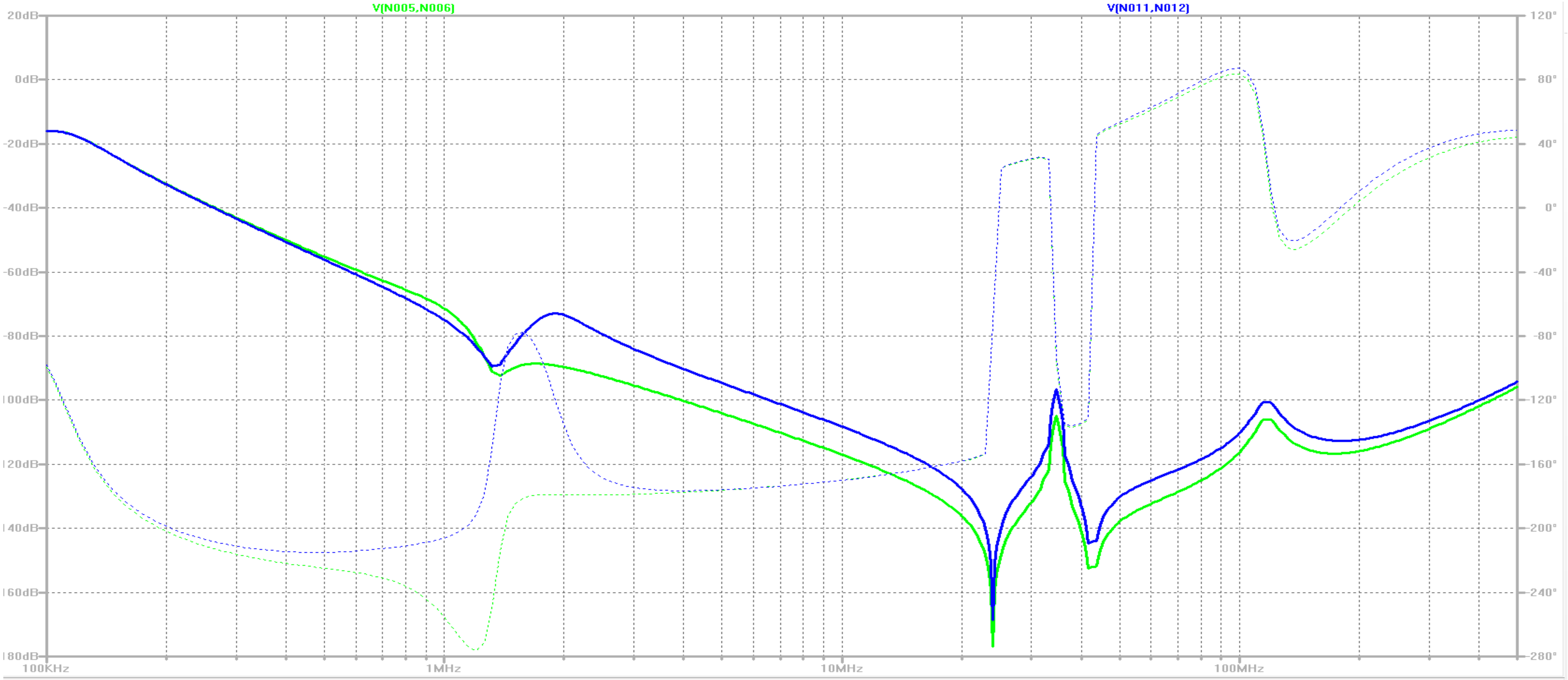


DIFFERENTIAL MODE FILTER FOR DESIGN (B)

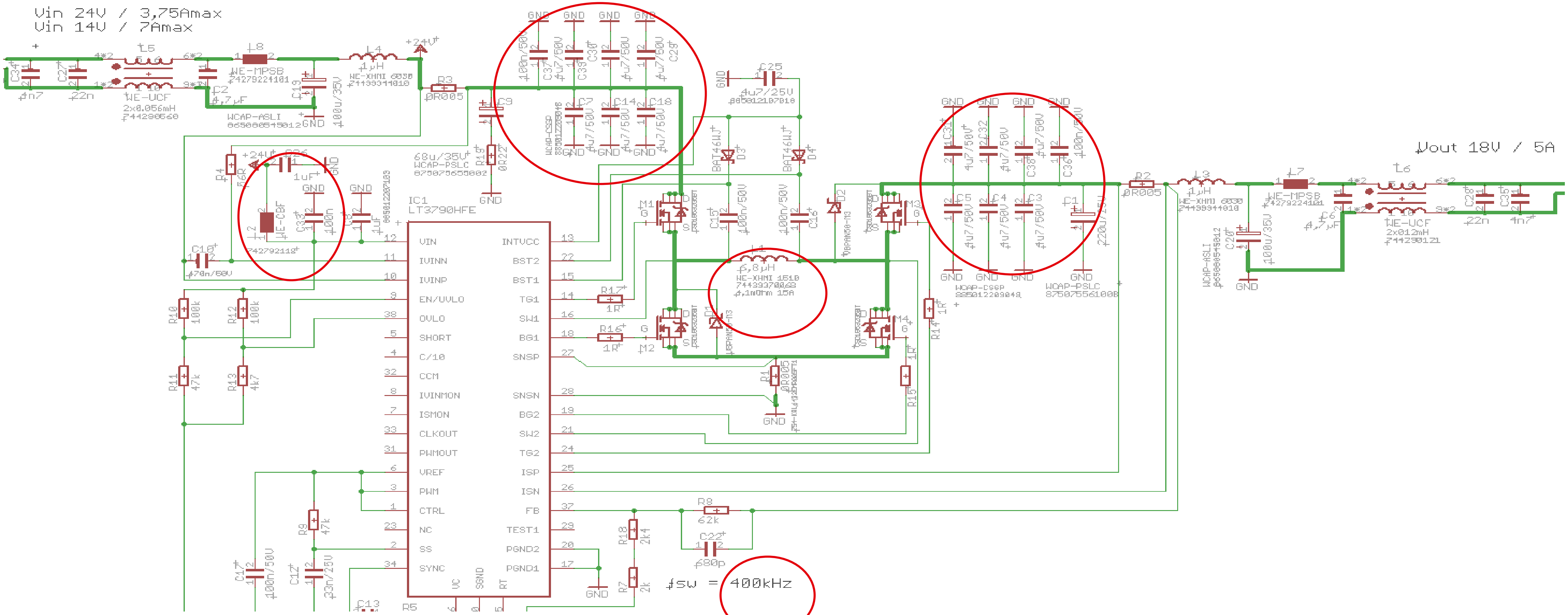
- All components with they parasitics considered for the simulation
- Losses at the Output Filter : $I^2 * Rdc = 5{,}5A^2 * 30m\Omega = \underline{907mW}$
- Losses at the Input Filter: $I^2 * Rdc = 7A^2 * 18{,}4m\Omega = \underline{902mW}$



FILTER FOR DESIGN (B)



SCHEMATIC FOR DESIGN (B)

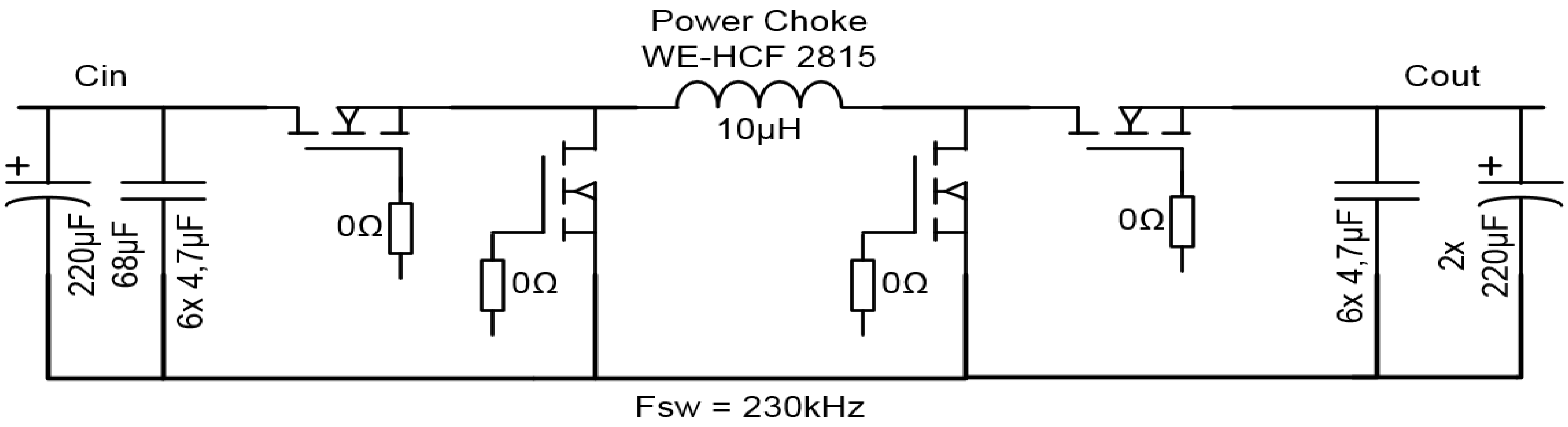


DESIGN (C)

DESIGN (C)

- Top and bottom side using components
- 6 Layer PCB
- Lowest switching freg → 230kHz → to achive lowest losses and highest efficiency → big inductor value / big cap values / no Gate resistors
- Different filters like design B used

➢ Most expensive / biggest size on PCB

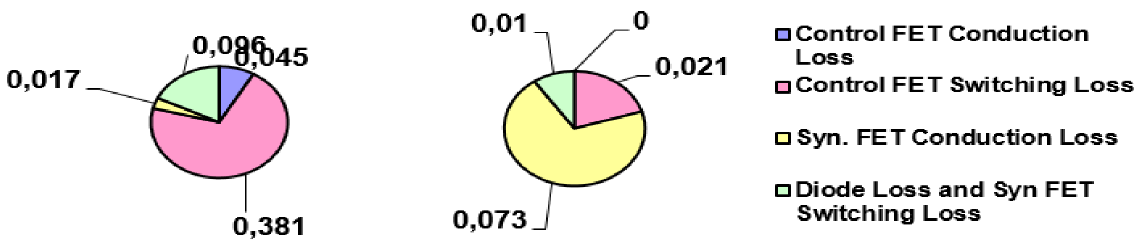


MOSFETS FOR DESIGN (C)

- **Logic Level N-Kanal FET im SON 5x6 same like used in Design (B)**

Estimated Power dissipation of each FET at full load, [P_{SYN}]=	0,02	0,07	W
Estimated Junction temperature, [Tj]=	50,02	50,06	°C

MOSFETs Power Loss Break Down (W)

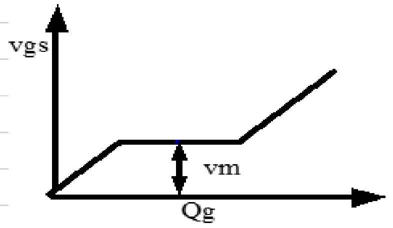


Buck Leg (A,B)　　Boost Leg(C,D)

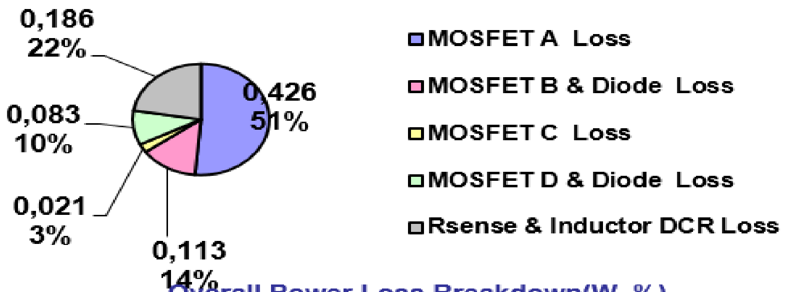
Estimated Efficiency

Overall estimated efficiency @ full load, [η]=	98,51	%

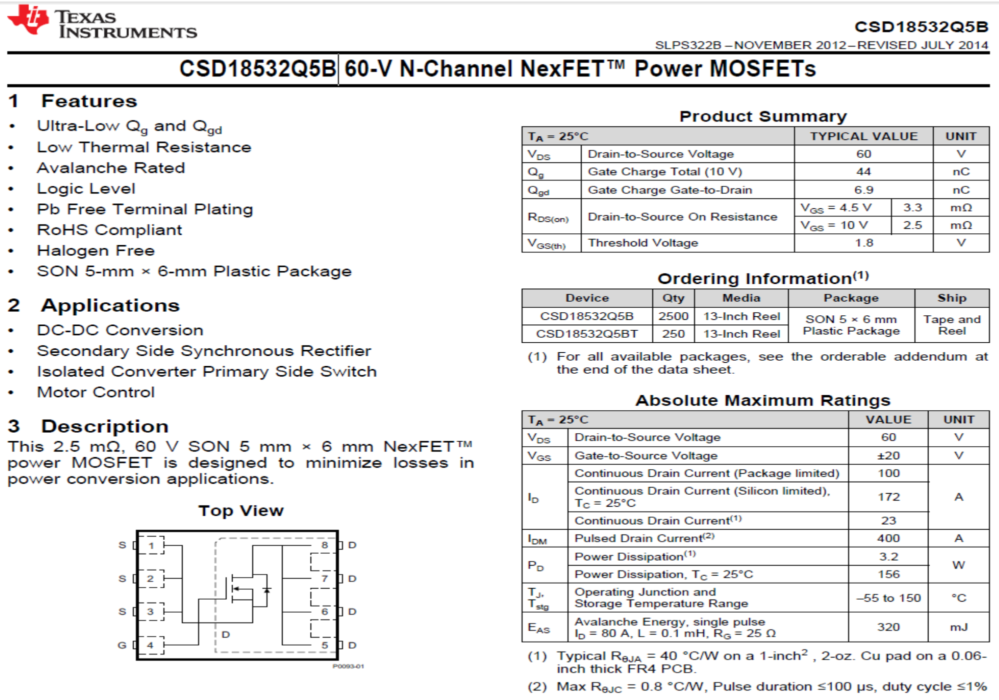
estimated.



Definition of FET Vm on Vgs Vs. Qg curve



Overall Power Loss Breakdown(W, %)



TEXAS INSTRUMENTS　CSD18532Q5B

SLPS322B – NOVEMBER 2012 – REVISED JULY 2014

CSD18532Q5B 60-V N-Channel NexFET™ Power MOSFETs

1 Features

- Ultra-Low Q_g and Q_{gd}
- Low Thermal Resistance
- Avalanche Rated
- Logic Level
- Pb Free Terminal Plating
- RoHS Compliant
- Halogen Free
- SON 5-mm × 6-mm Plastic Package

2 Applications

- DC-DC Conversion
- Secondary Side Synchronous Rectifier
- Isolated Converter Primary Side Switch
- Motor Control

3 Description

This 2.5 mΩ, 60 V SON 5 mm × 6 mm NexFET™ power MOSFET is designed to minimize losses in power conversion applications.

Top View

Product Summary

T_A = 25°C		TYPICAL VALUE		UNIT
V_{DS}	Drain-to-Source Voltage	60		V
Q_g	Gate Charge Total (10 V)	44		nC
Q_{gd}	Gate Charge Gate-to-Drain	6.9		nC
$R_{DS(on)}$	Drain-to-Source On Resistance	V_{GS} = 4.5 V	3.3	mΩ
		V_{GS} = 10 V	2.5	mΩ
$V_{GS(th)}$	Threshold Voltage	1.8		V

Ordering Information(1)

Device	Qty	Media	Package	Ship
CSD18532Q5B	2500	13-Inch Reel	SON 5 × 6 mm Plastic Package	Tape and Reel
CSD18532Q5BT	250	13-Inch Reel		

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Absolute Maximum Ratings

T_A = 25°C		VALUE	UNIT
V_{DS}	Drain-to-Source Voltage	60	V
V_{GS}	Gate-to-Source Voltage	±20	V
I_D	Continuous Drain Current (Package limited)	100	A
	Continuous Drain Current (Silicon limited), T_C = 25°C	172	
	Continuous Drain Current(1)	23	
I_{DM}	Pulsed Drain Current(2)	400	A
P_D	Power Dissipation(1)	3.2	W
	Power Dissipation, T_C = 25°C	156	
T_J, T_{stg}	Operating Junction and Storage Temperature Range	–55 to 150	°C
E_{AS}	Avalanche Energy, single pulse I_D = 80 A, L = 0.1 mH, R_G = 25 Ω	320	mJ

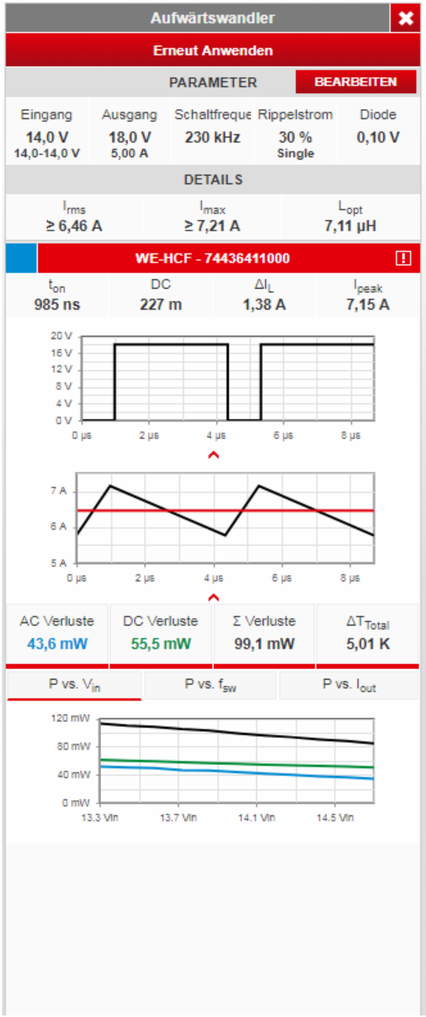
(1) Typical $R_{\theta JA}$ = 40 °C/W on a 1-inch^2, 2-oz. Cu pad on a 0.06-inch thick FR4 PCB.

(2) Max $R_{\theta JC}$ = 0.8 °C/W, Pulse duration ≤100 μs, duty cycle ≤1%

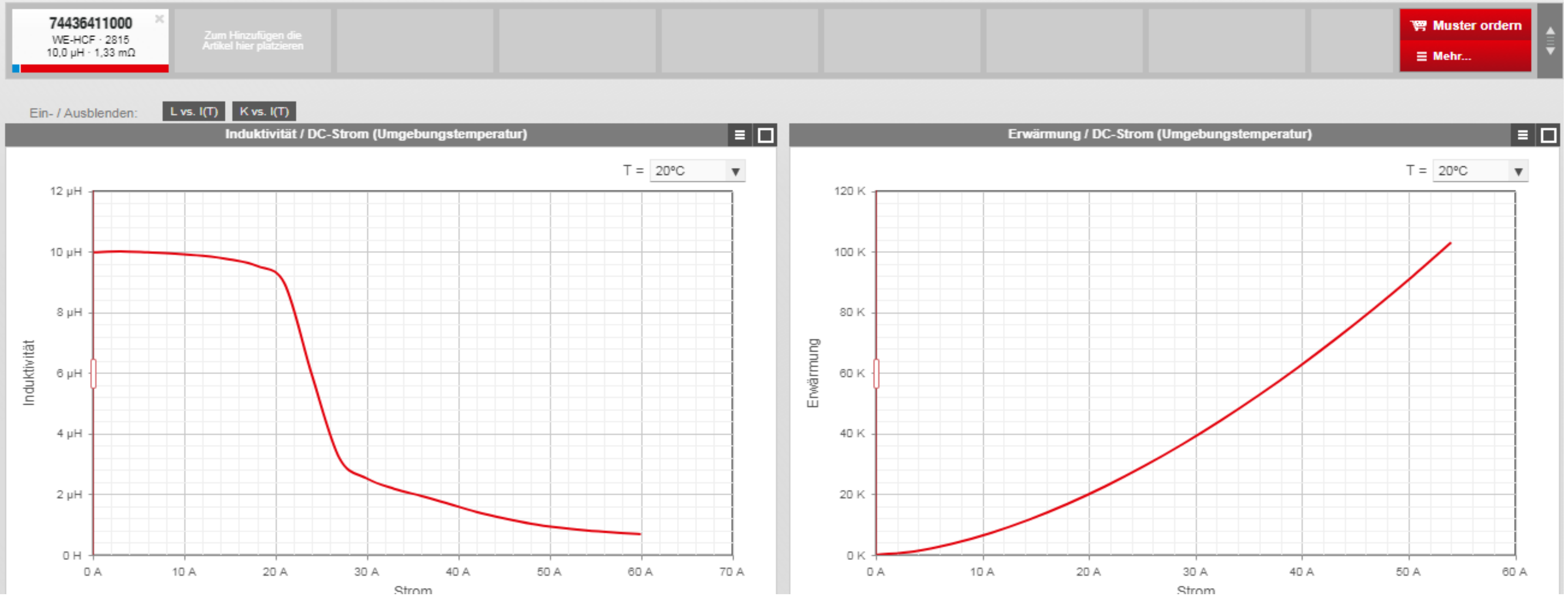
REDEXPERT: INDUCTOR SELECTION FOR DESIGN (C)

Boost Mode:

- AC loss = 0,04W
- DC loss = 0,06W
- Pv all = 0,1W
- ΔT = 5K
- Ipeak = 7,15A



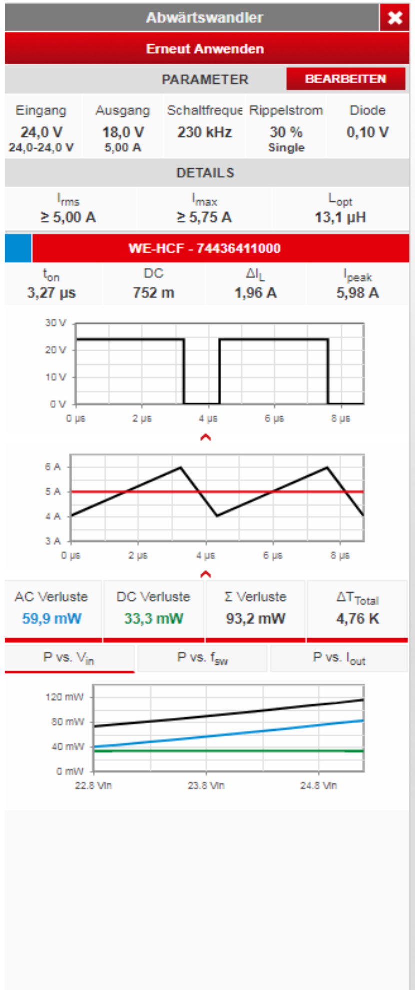
Artikel-Nr.	Serie	Bauform	Spez	Typ	L	$R_{DC,typ}$	I_R	I_{sat}	AC Verlu...	DC Verlu...	Gesamtv...	ΔT_{Total}
74436410220	WE-HCF	2815	PDF	Single	2,20 µH	1,33 mΩ	36,0 A	88,5 A	362 mW	55,5 mW	417 mW	16,4 K
74436410330	WE-HCF	2815	PDF	Single	3,30 µH	1,33 mΩ	36,0 A	60,5 A	138 mW	55,5 mW	194 mW	8,71 K
74436410470	WE-HCF	2815	PDF	Single	4,70 µH	1,33 mΩ	36,0 A	44,0 A	97,1 mW	55,5 mW	153 mW	7,16 K
74436410680	WE-HCF	2815	PDF	Single	6,80 µH	1,33 mΩ	36,0 A	30,0 A	64,1 mW	55,5 mW	120 mW	5,86 K
74436411000	WE-HCF	2815	PDF	Single	10,0 µH	1,33 mΩ	36,0 A	21,5 A	43,6 mW	55,5 mW	99,1 mW	5,01 K
74436411500	WE-HCF	2815	PDF	Single	15,0 µH	1,33 mΩ	36,0 A	14,3 A	29,1 mW	55,5 mW	84,6 mW	4,40 K
74436412200	WE-HCF	2815	PDF	Single	22,0 µH	1,33 mΩ	36,0 A	9,50 A	40,1 mW	55,5 mW	95,6 mW	4,86 K

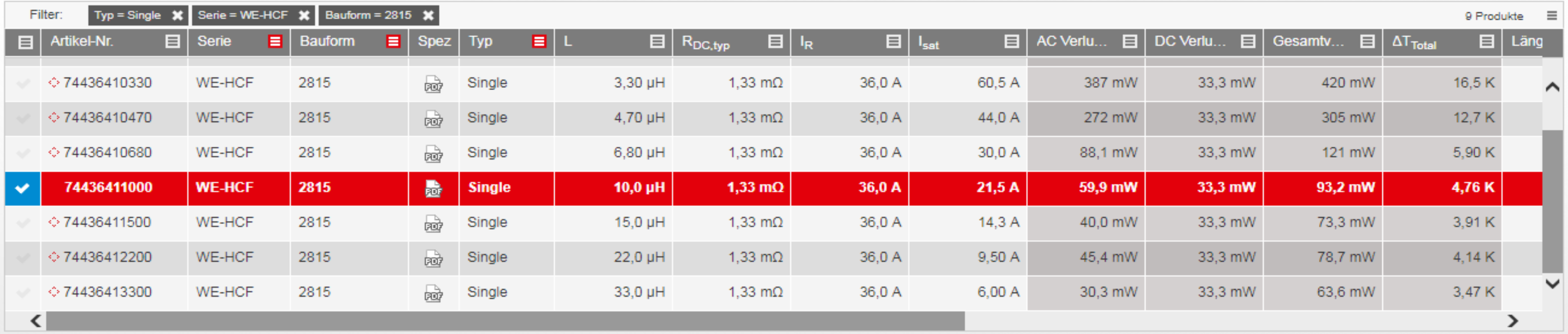


REDEXPERT: INDUCTOR SELECTION FOR DESIGN (C)

Buck Mode:

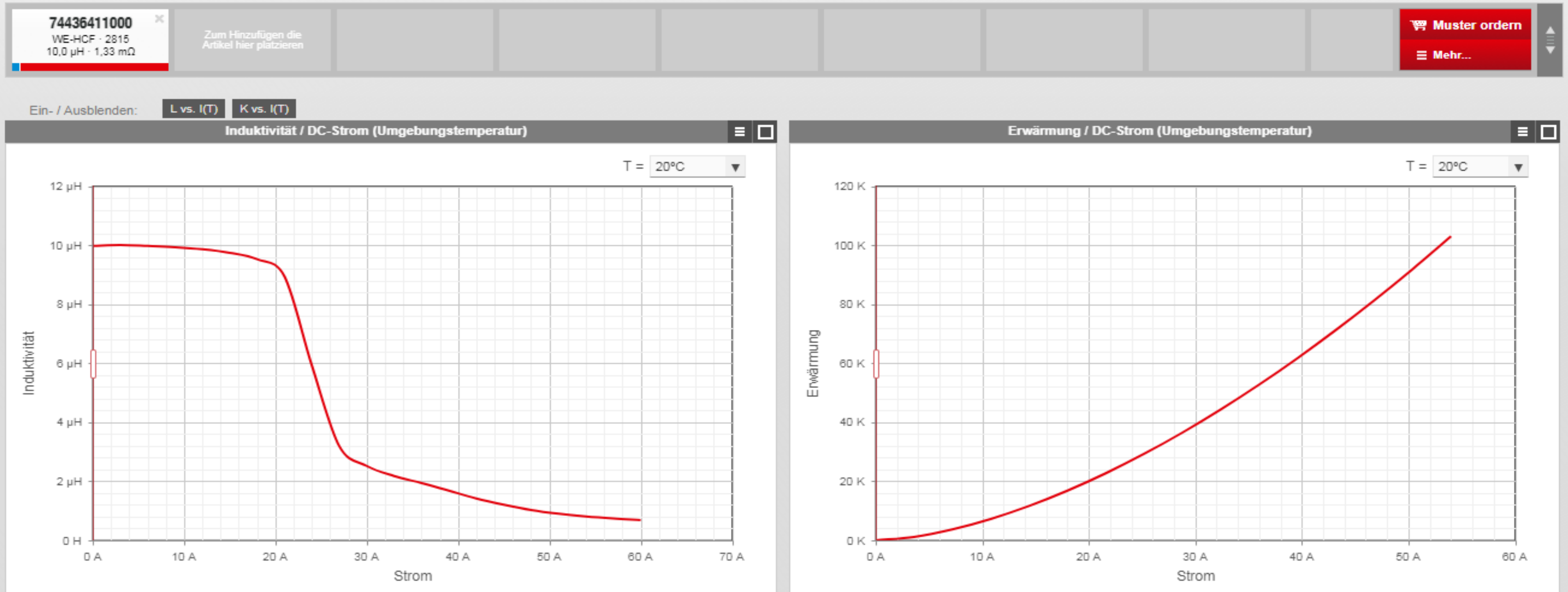
- AC loss = 0,06W
- DC loss = 0,03W
- Pv all = 0,09W
- ΔT = 4,8 K
- Ipeak = 5,98A





Filter: Typ = Single | Serie = WE-HCF | Bauform = 2815 — 9 Produkte

Artikel-Nr.	Serie	Bauform	Spez	Typ	L	$R_{DC,typ}$	I_R	I_{sat}	AC Verlu...	DC Verlu...	Gesamtv...	ΔT_{Total}
74436410330	WE-HCF	2815	PDF	Single	3,30 µH	1,33 mΩ	36,0 A	60,5 A	387 mW	33,3 mW	420 mW	16,5 K
74436410470	WE-HCF	2815	PDF	Single	4,70 µH	1,33 mΩ	36,0 A	44,0 A	272 mW	33,3 mW	305 mW	12,7 K
74436410680	WE-HCF	2815	PDF	Single	6,80 µH	1,33 mΩ	36,0 A	30,0 A	88,1 mW	33,3 mW	121 mW	5,90 K
74436411000	WE-HCF	2815	PDF	Single	10,0 µH	1,33 mΩ	36,0 A	21,5 A	59,9 mW	33,3 mW	93,2 mW	4,76 K
74436411500	WE-HCF	2815	PDF	Single	15,0 µH	1,33 mΩ	36,0 A	14,3 A	40,0 mW	33,3 mW	73,3 mW	3,91 K
74436412200	WE-HCF	2815	PDF	Single	22,0 µH	1,33 mΩ	36,0 A	9,50 A	45,4 mW	33,3 mW	78,7 mW	4,14 K
74436413300	WE-HCF	2815	PDF	Single	33,0 µH	1,33 mΩ	36,0 A	6,00 A	30,3 mW	33,3 mW	63,6 mW	3,47 K



INDUCTOR SELECTION FOR DESIGN (C)

- **Fsw at 230kHz → 30% max. ripple current → Inductor value ca. 10µH**

- Selected with REDEXPERT
- Selected Type of inductor: WE-HCF
  - Flat wire and shielded
  - Size 2815 (28x27x15mm)
  - Nominal current : 36A
  - Saturation current : 21,5A
  - Rdc : 1,33mΩ

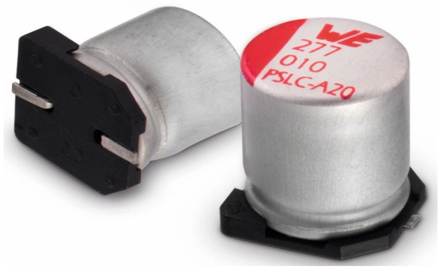
INPUT CAPACITOR SELECTION FOR DESIGN(C)

- Calculation for Cin using MLCC X7R for max allowed ripple current

$$C_{in} \geq \frac{D \times (1 - D) \times I_{outmax}}{\Delta V_{in\,pp} \times f_{sw}}$$

$$C_{in} \geq \frac{0{,}78 \times (1 - 0{,}78) \times 5A}{20mVpp \times 230kHz} = 186\mu F$$

➢ Selected : 7 x 4,7µF / 50V / X7R = 33µF – 20% DC-Bias = 26,3µF



➢ Additional: Parallel to the MLCCs 1x 220µF/35V Al-Polymer WCAP-PSLC

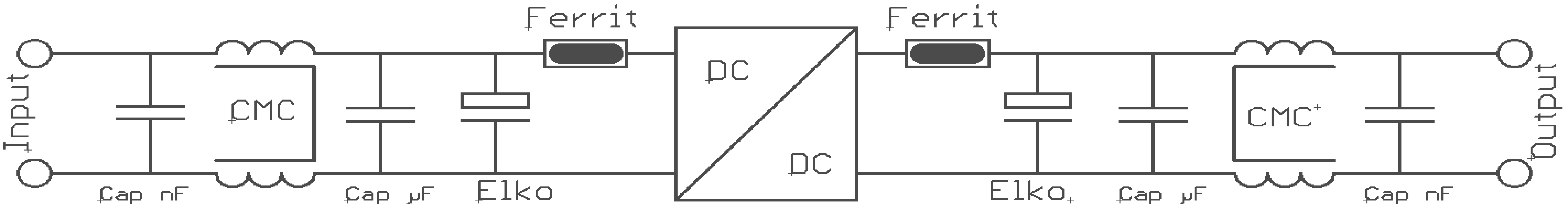
FILTER FOR DESIGN (C)

- Filter for Conducted und Radiated Emission Test Spectrum

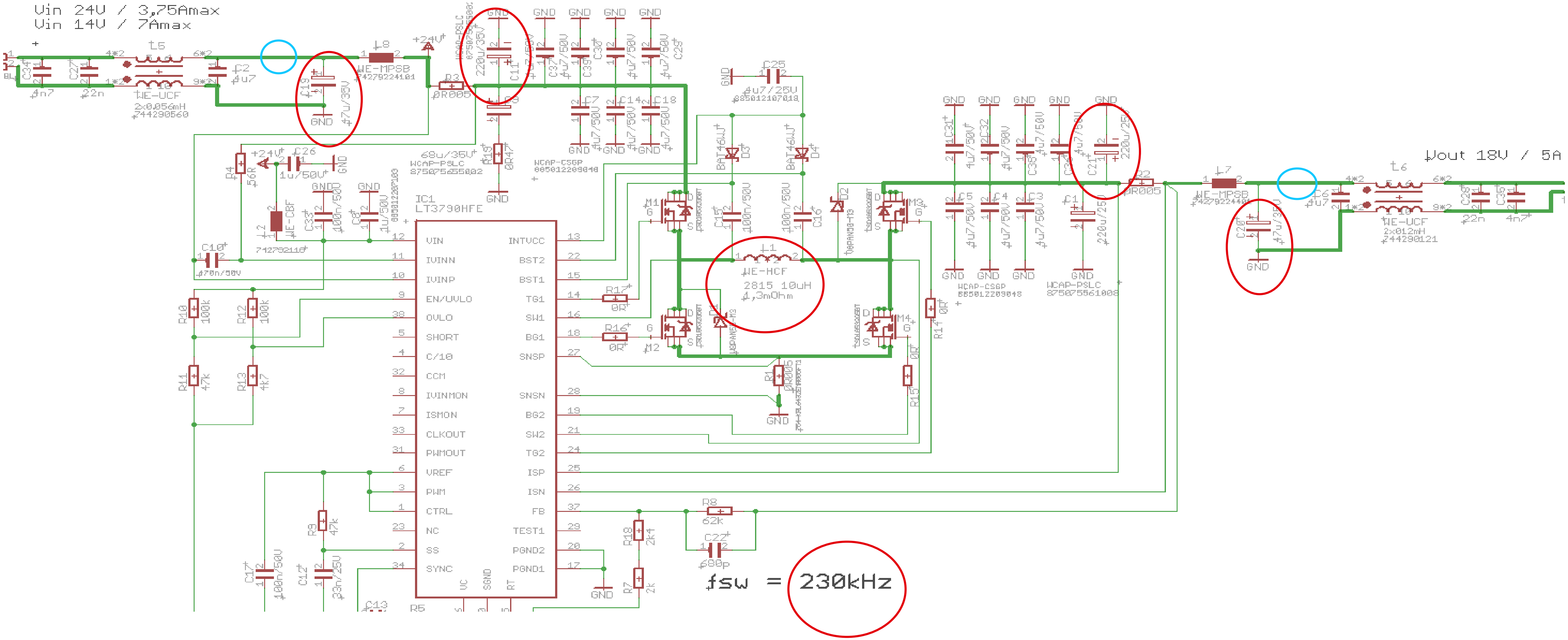
- Target: increase the efficiency compared with design (B)

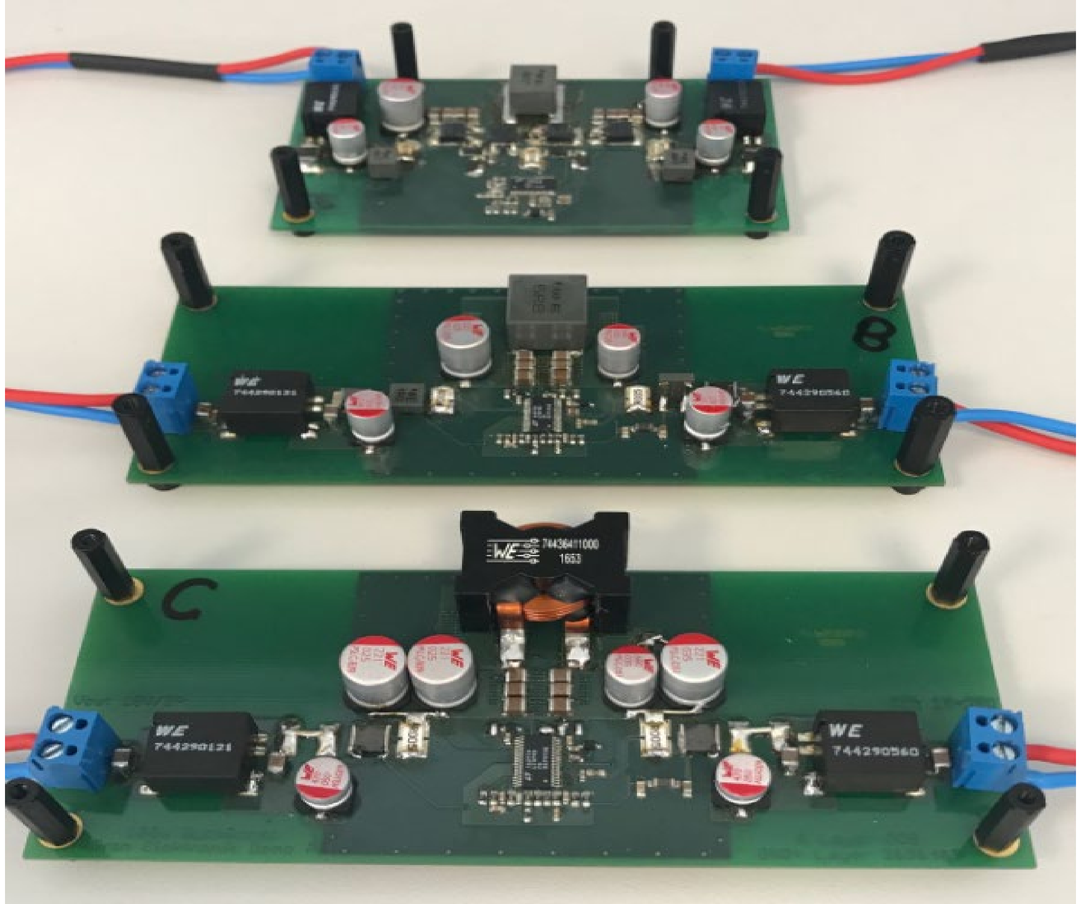
➢ Skip the 1µH Inductor from design (B) → big influence up to 5MHz

➢ Filter Caps from 100µF reduced to 47uF, in rest same components used



SCHEMATIC FOR DESIGN (C)

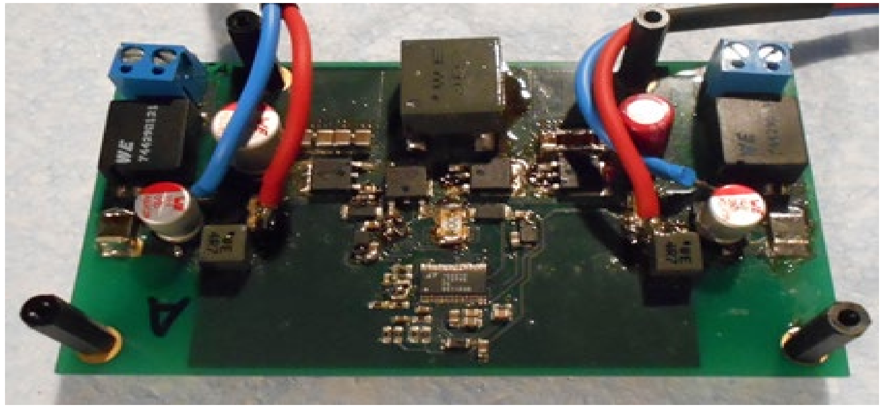


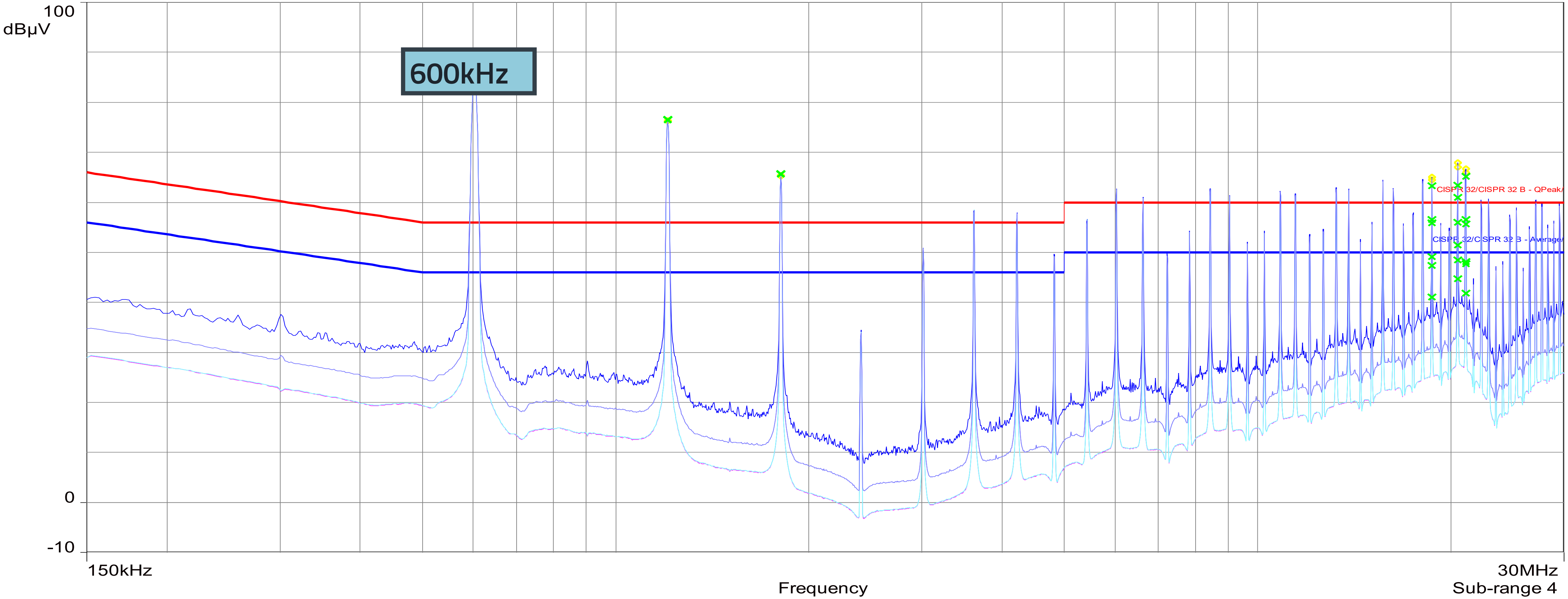


EMC MEASUREMENTS CONDUCTED & RADIATED

MEASURED WITH ENV216 LISN & ESRP

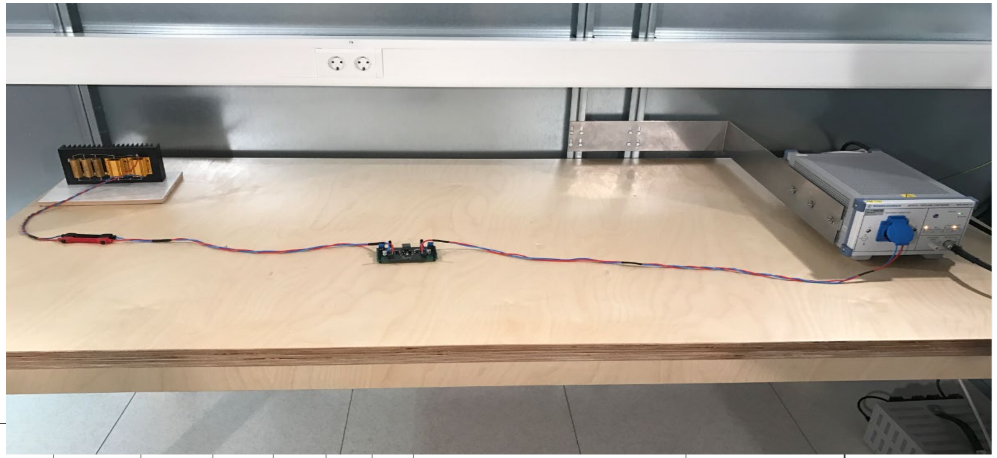
- Conducted Emission 150kHz – 30MHz
- Design (A) without Filter / Buck Mode 100W

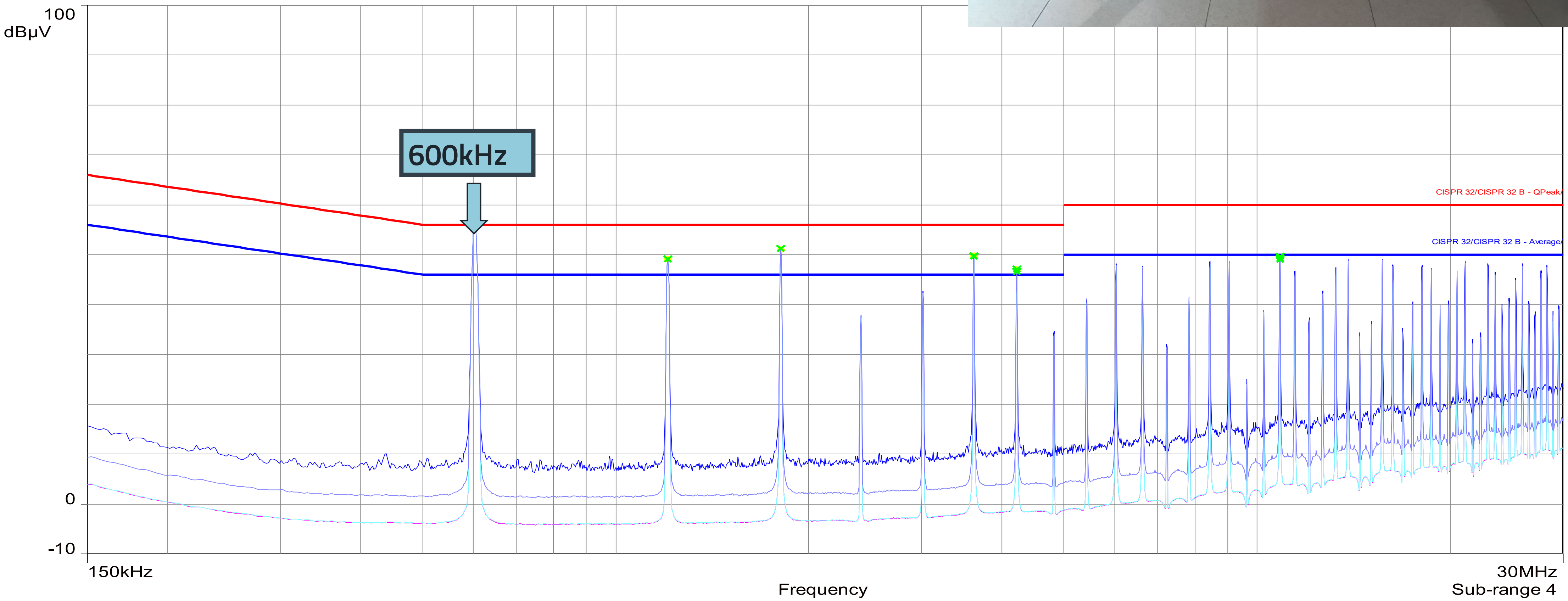




MEASURED WITH ENV216 LISN & ESRP

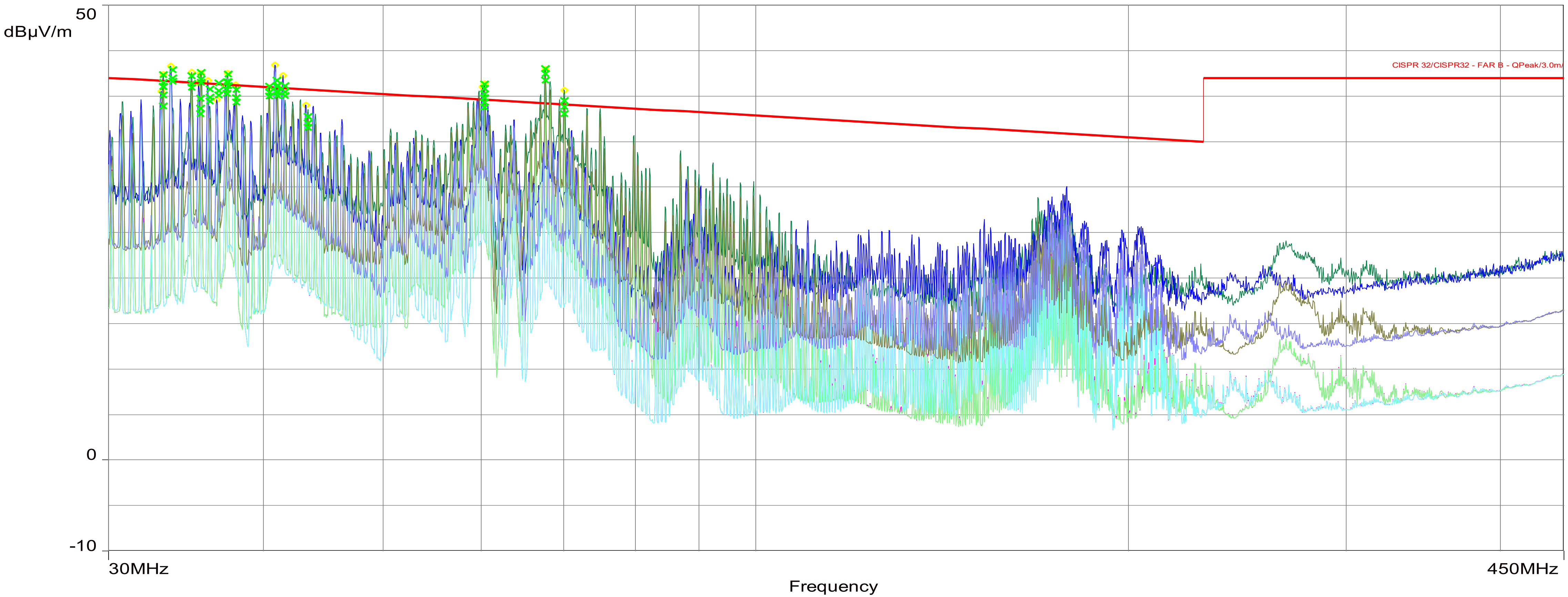
- Conducted Emission 150kHz – 30MHz
- Design (A) with Filter / Buck Mode 100W





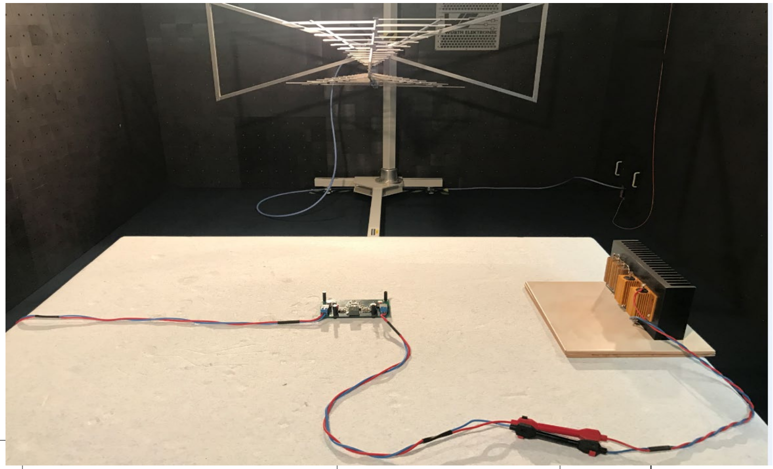
MEASUREMENT IN EMC CHAMBER

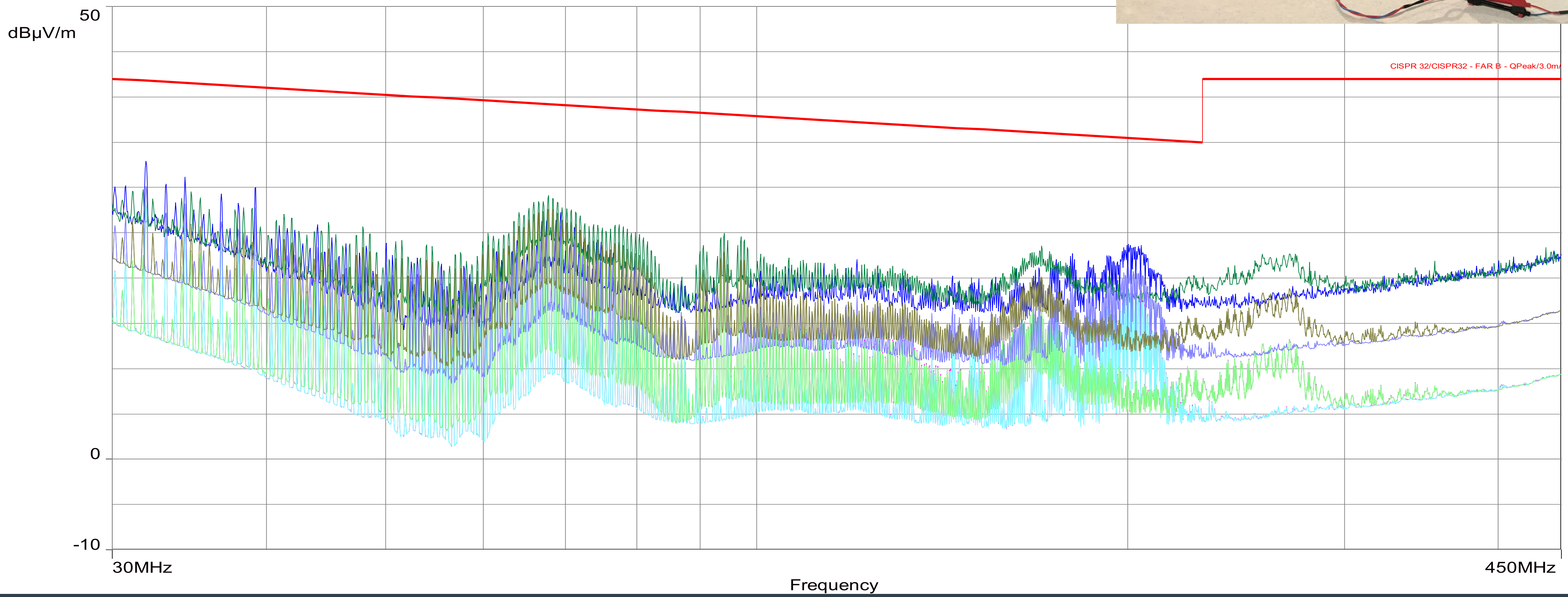
- Radiated Emission 30MHz – 450MHz
- Design (A) without Filter / Buck Mode 100W



MEASUREMENT IN EMC CHAMBER

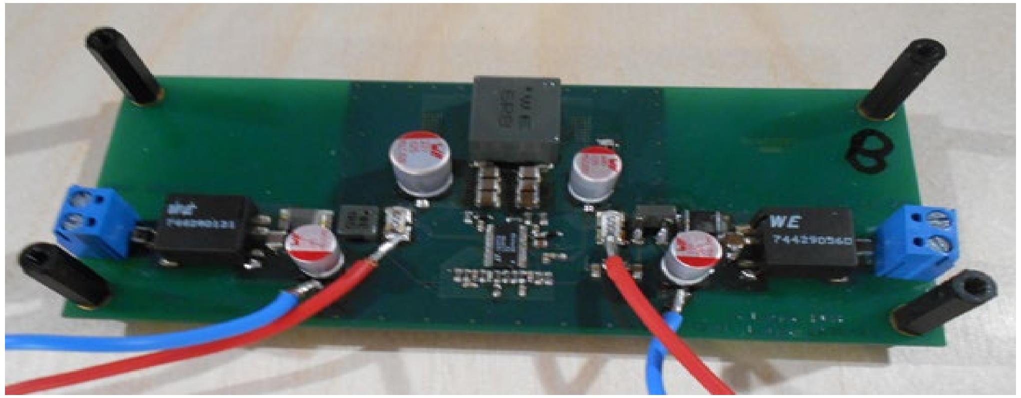
- Radiated Emission 30MHz – 450MHz
- Design (A) with Filter / Buck Mode 100W

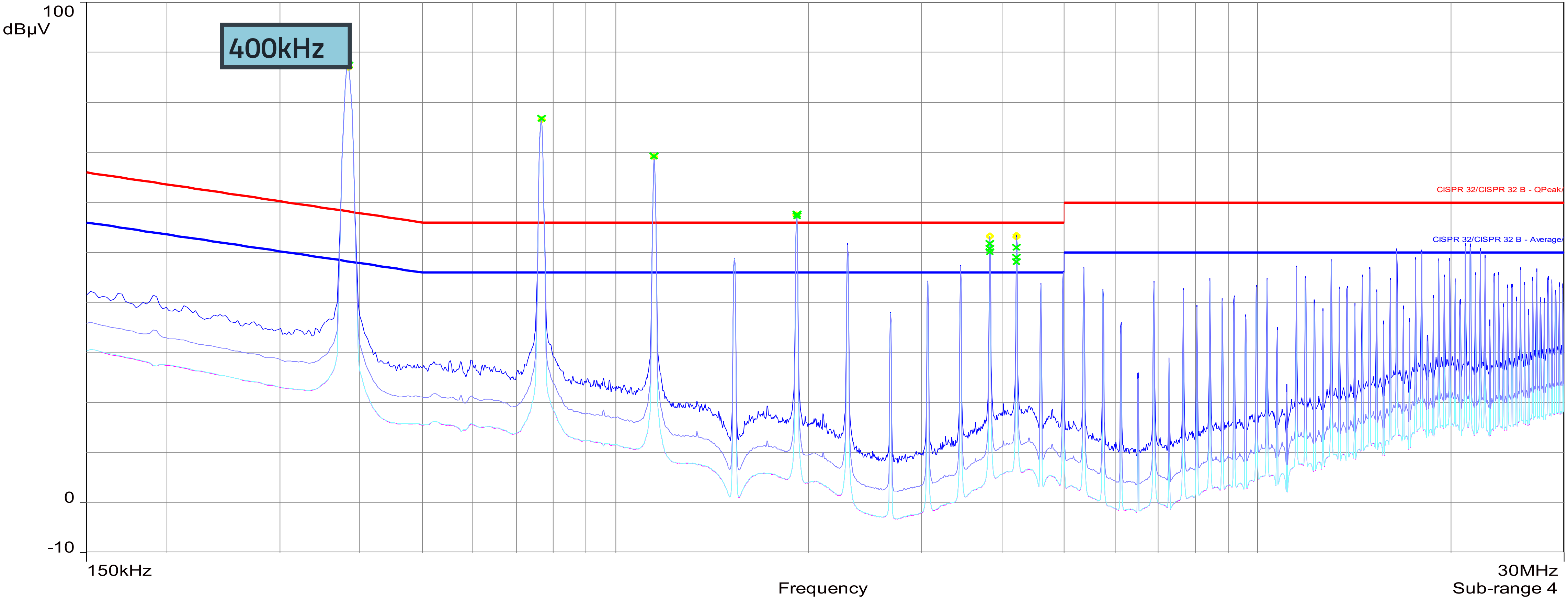




MEASURED WITH ENV216 LISN & ESRP

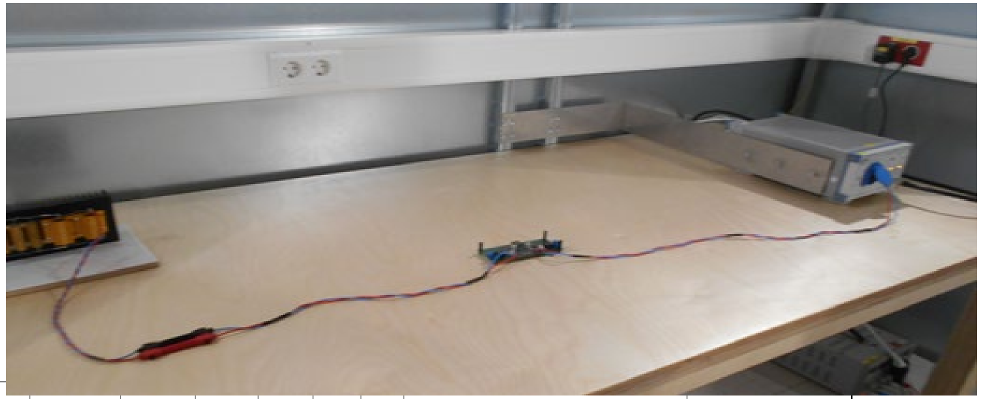
- Conducted Emission 150kHz – 30MHz
- Design (B) without Filter / Buck Mode 100W

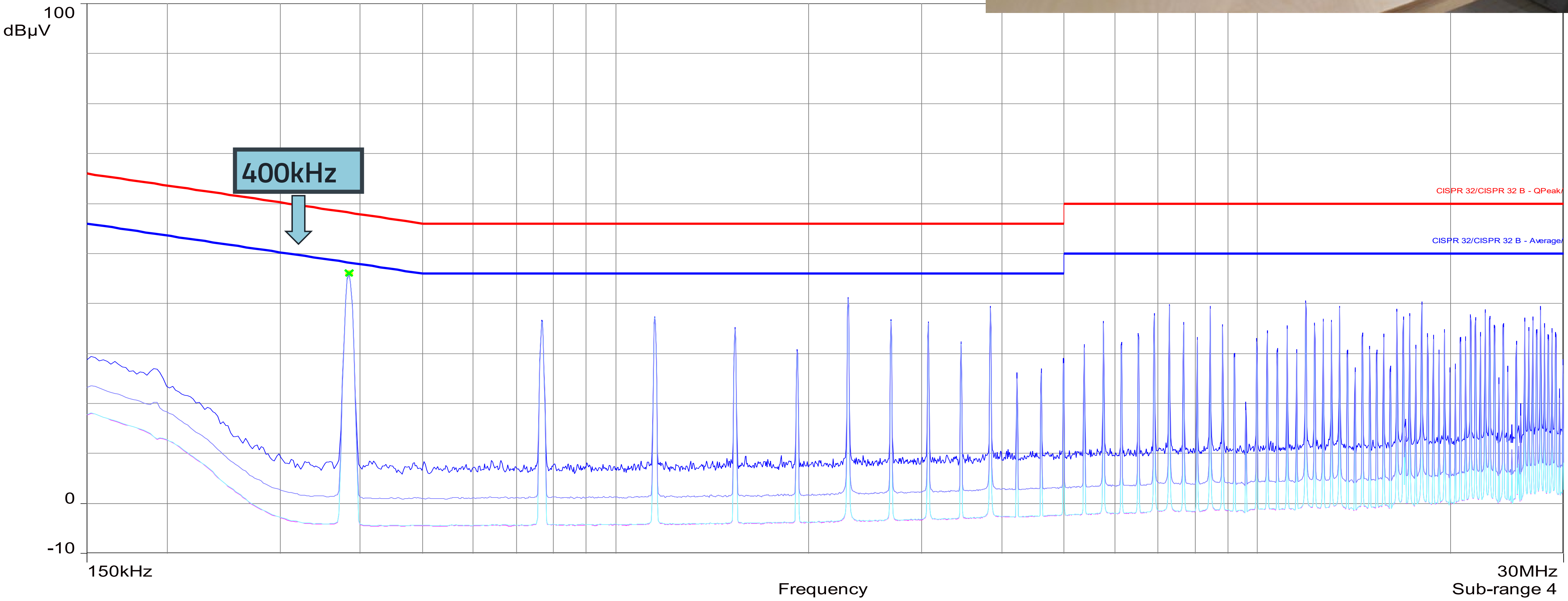




MEASURED WITH ENV216 LISN & ESRP

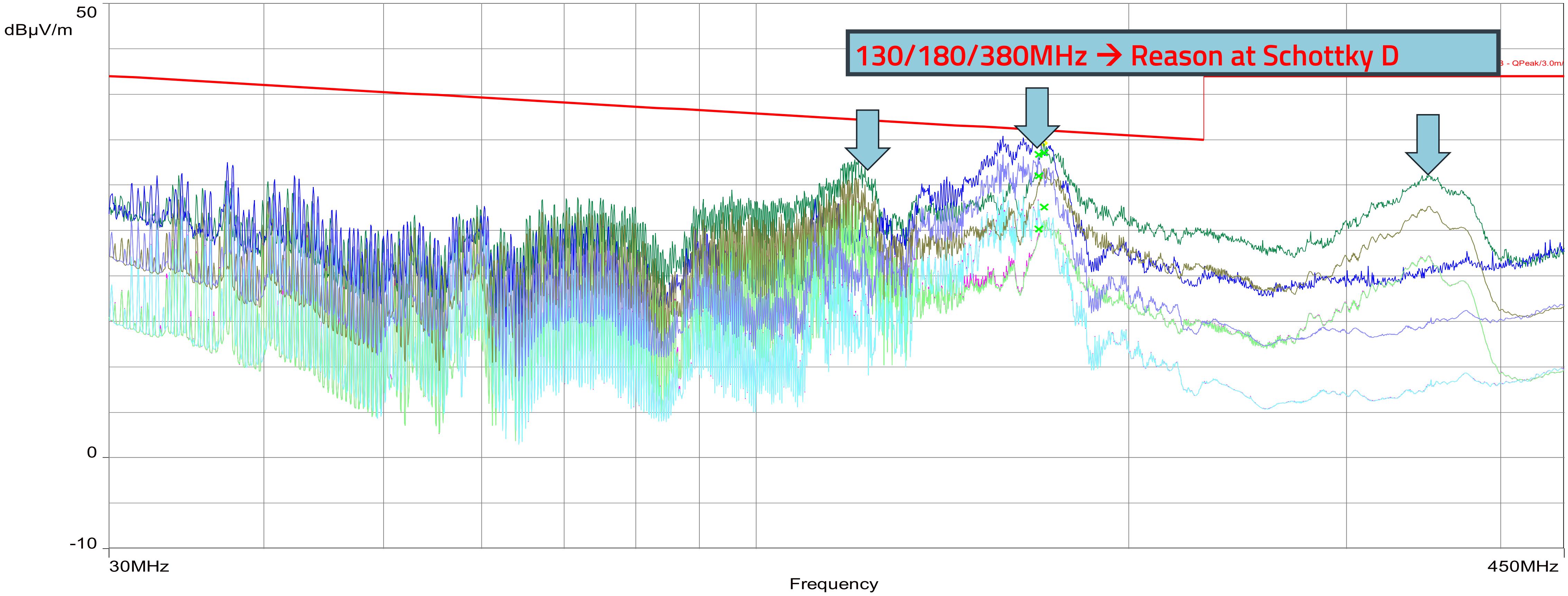
- Conducted Emission 150kHz – 30MHz
- Design (B) with Filter / Buck Mode 100W





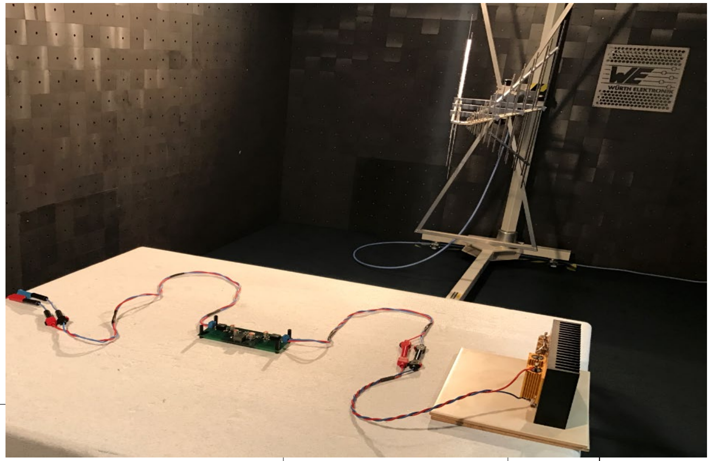
MEASUREMENT IN EMC CHAMBER

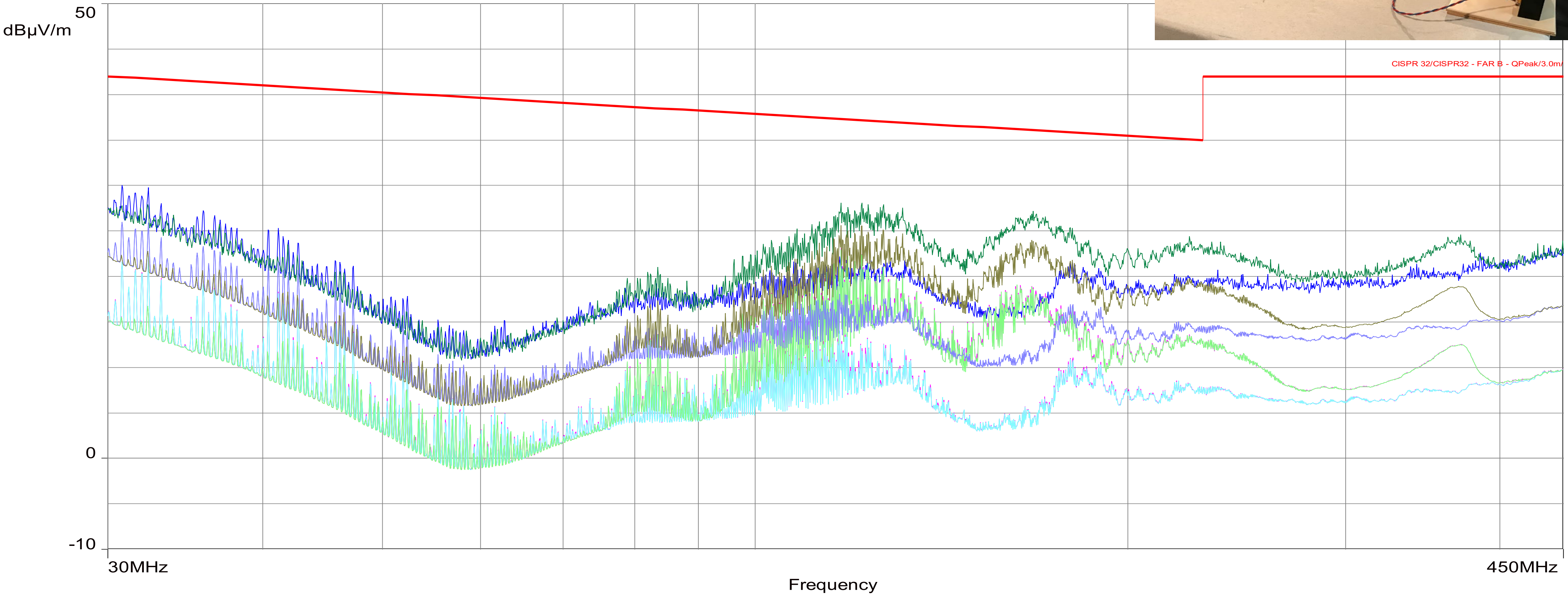
- Radiated Emission 30MHz – 450MHz
- Design (B) without Filter / Buck Mode 100W



MEASUREMENT IN EMC CHAMBER

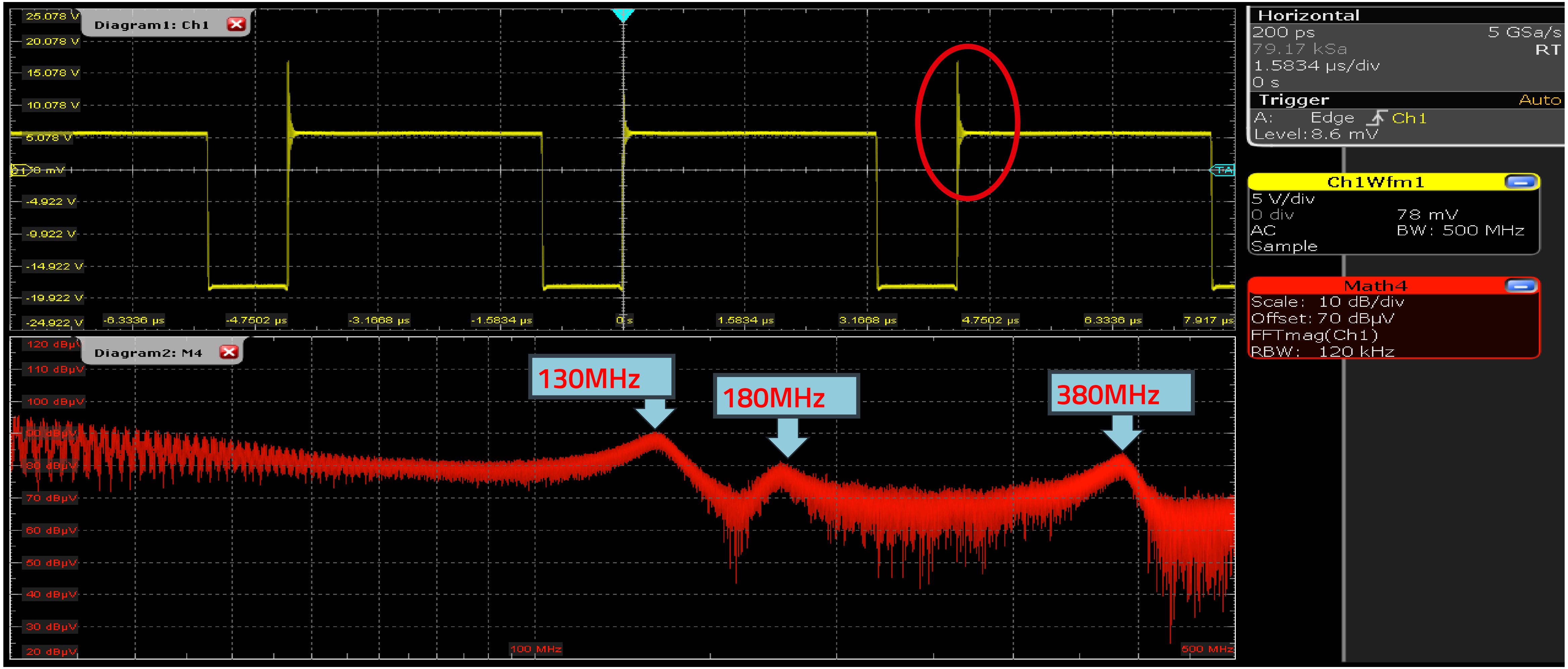
- Radiated Emission 30MHz – 450MHz
- Design (B) with Filter / Buck Mode 100W





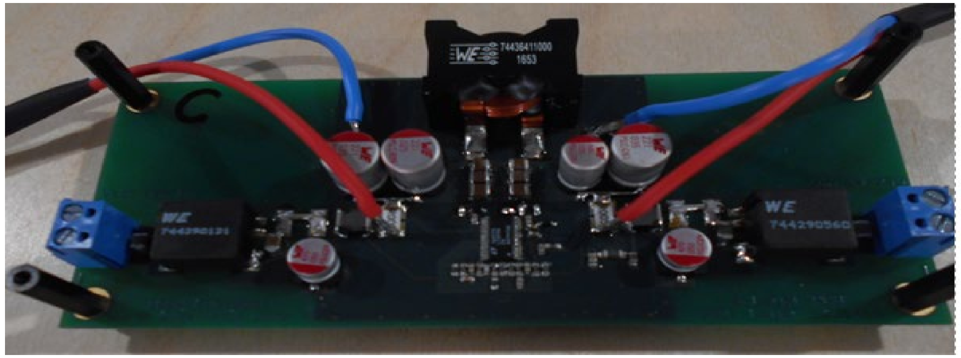
MEASUREMENT AT THE SCHOTTKY

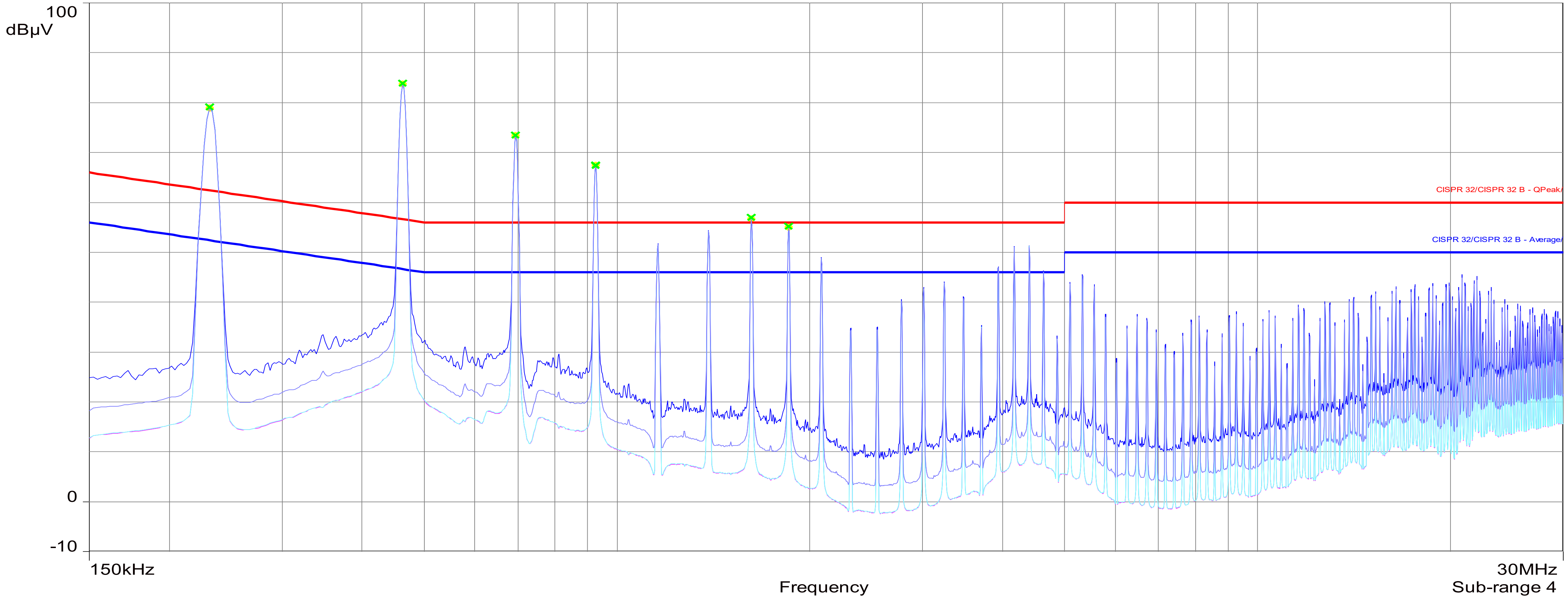
- Measured with R&S RTO at the Schottky D (Buck Leg)



MEASURED WITH ENV216 LISN & ESRP

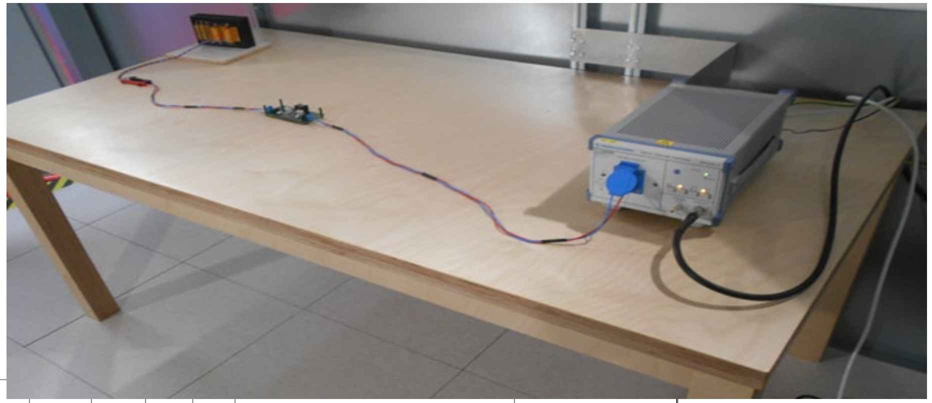
- Conducted Emission 150kHz – 30MHz
- Design (C) without Filter / Buck Mode 100W

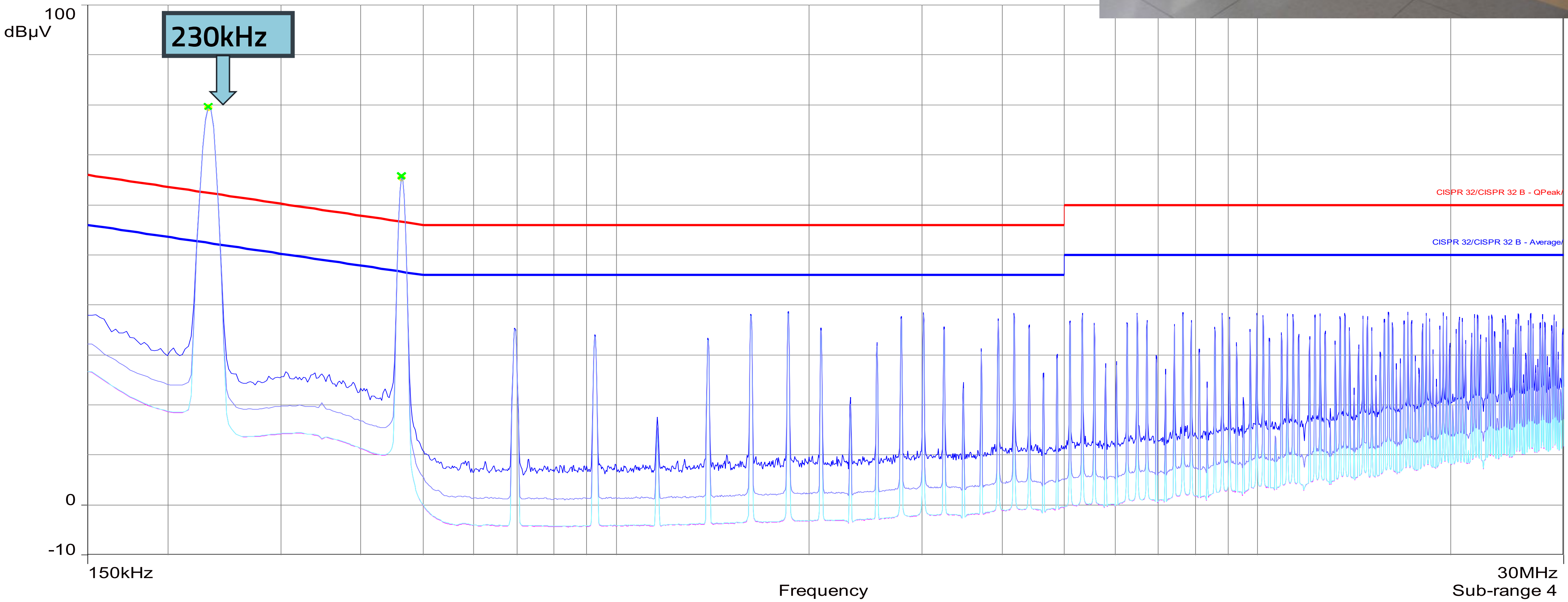




MEASURED WITH ENV216 LISN & ESRP

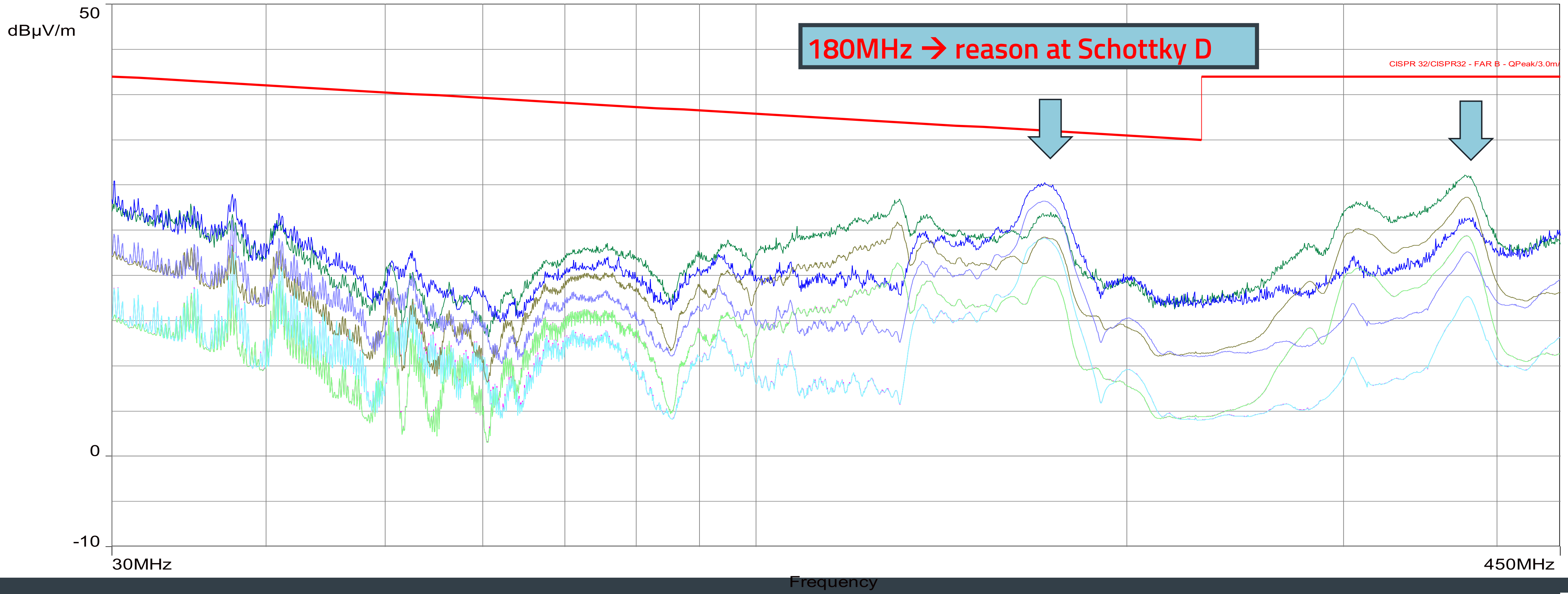
- Conducted Emission 150kHz – 30MHz
- Design (C) with Filter / Buck Mode 100W





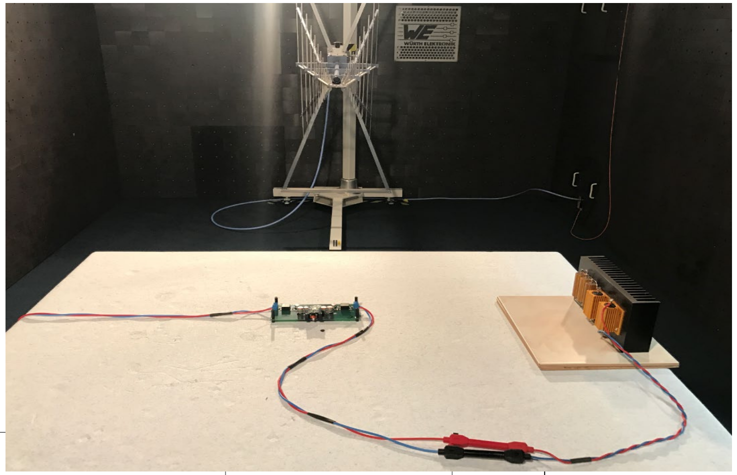
MEASUREMENT IN EMC CHAMBER

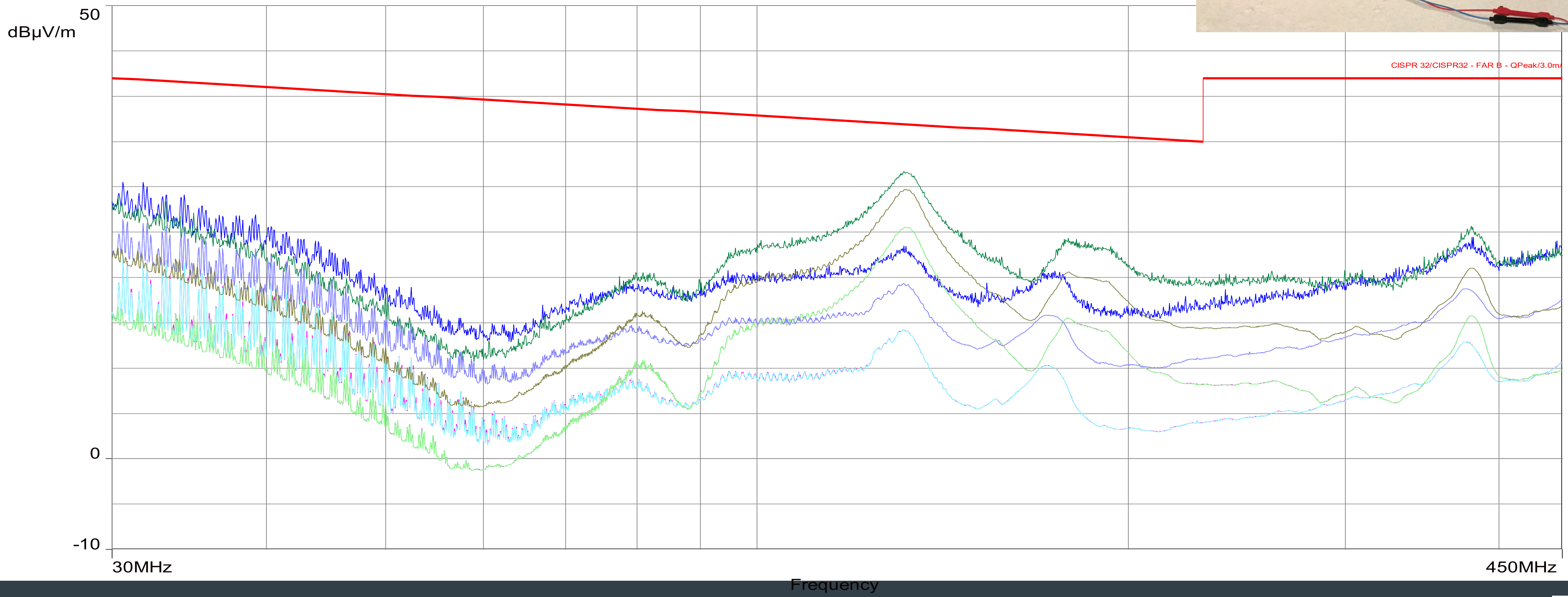
- Radiated Emission 30MHz – 450MHz
- Design (C) without Filter / Buck Mode 100W



MEASUREMENT IN EMC CHAMBER

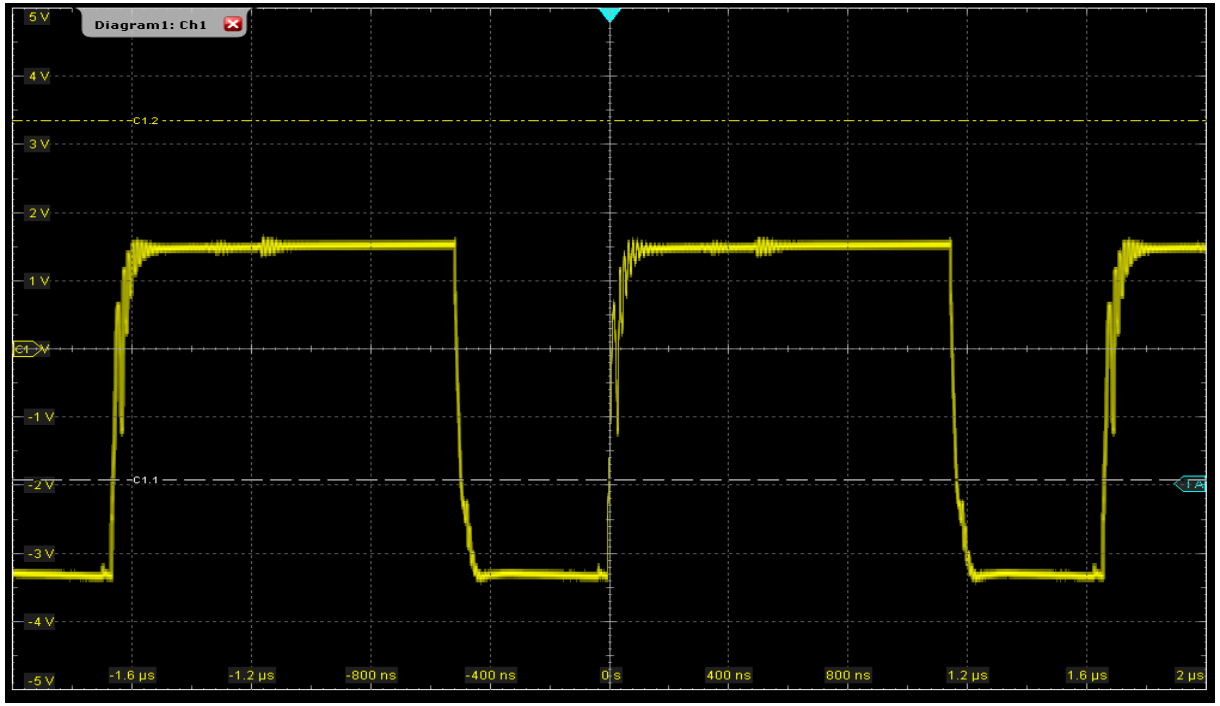
- Radiated Emission 30MHz – 450MHz
- Design (C) with Filter / Buck Mode 100W

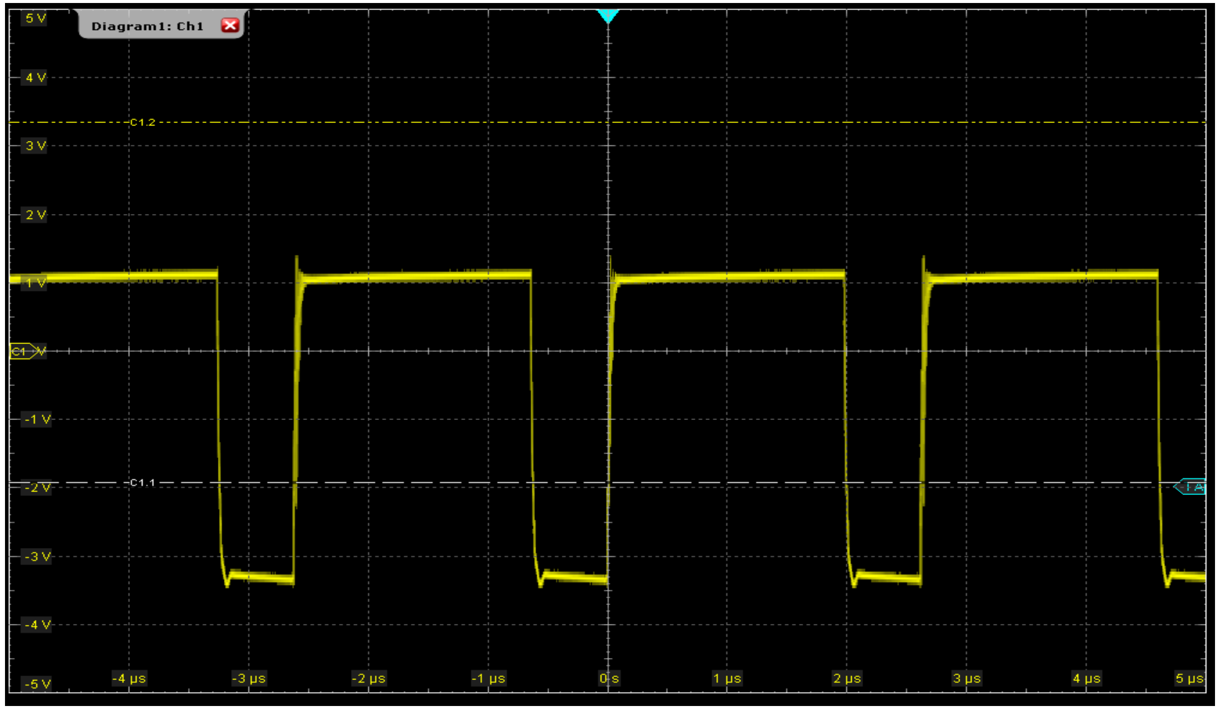




MEASURING DIRECT AT THE COMPONENTS

GATE SOURCE VOLTAGE FROM HIGH SIDE FET

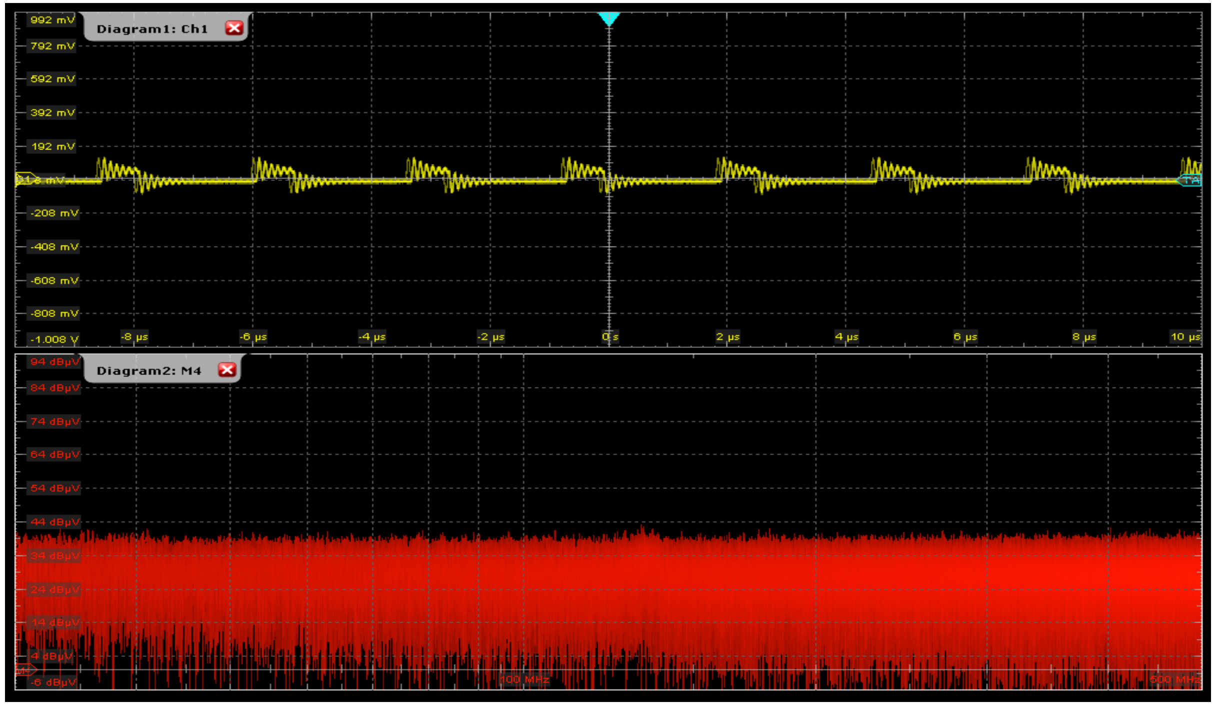


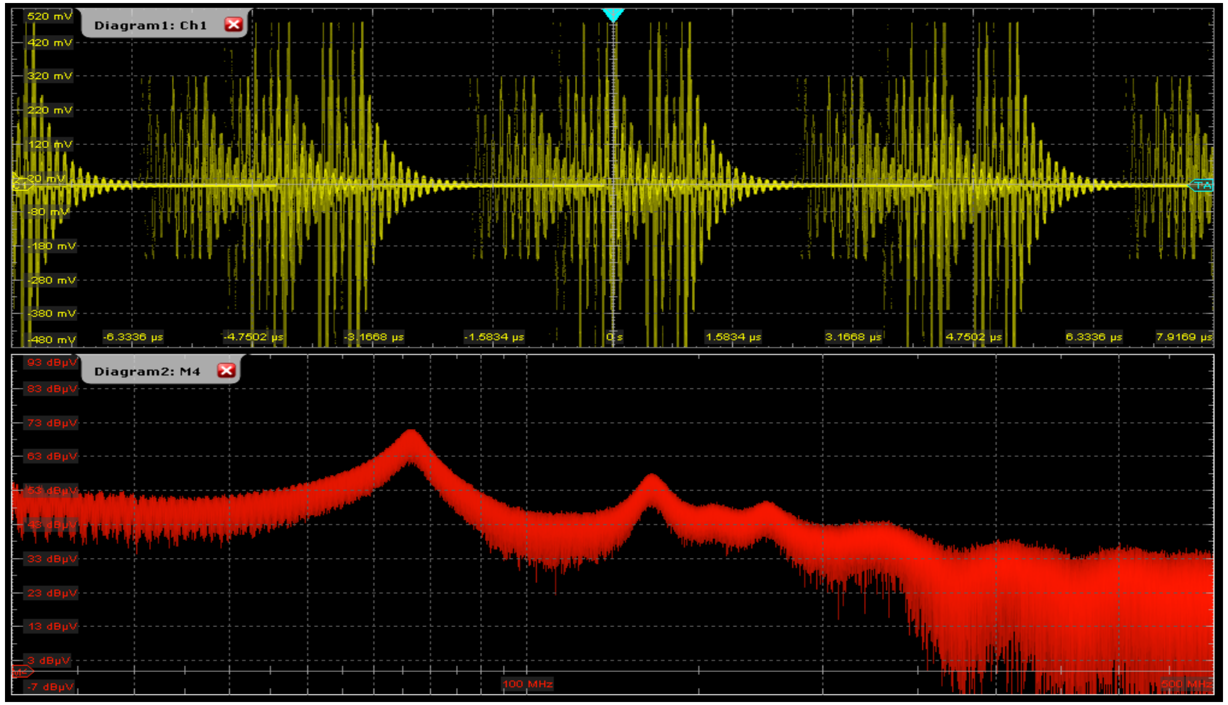


- **Vgs Design (A)**
- **Vgs Design (B)**

Reason: The improved layout and the smaller package of the MOSFET

MEASURED WITH H-FIELD PROBE DESIGN (B) 30MHZ-500MHZ

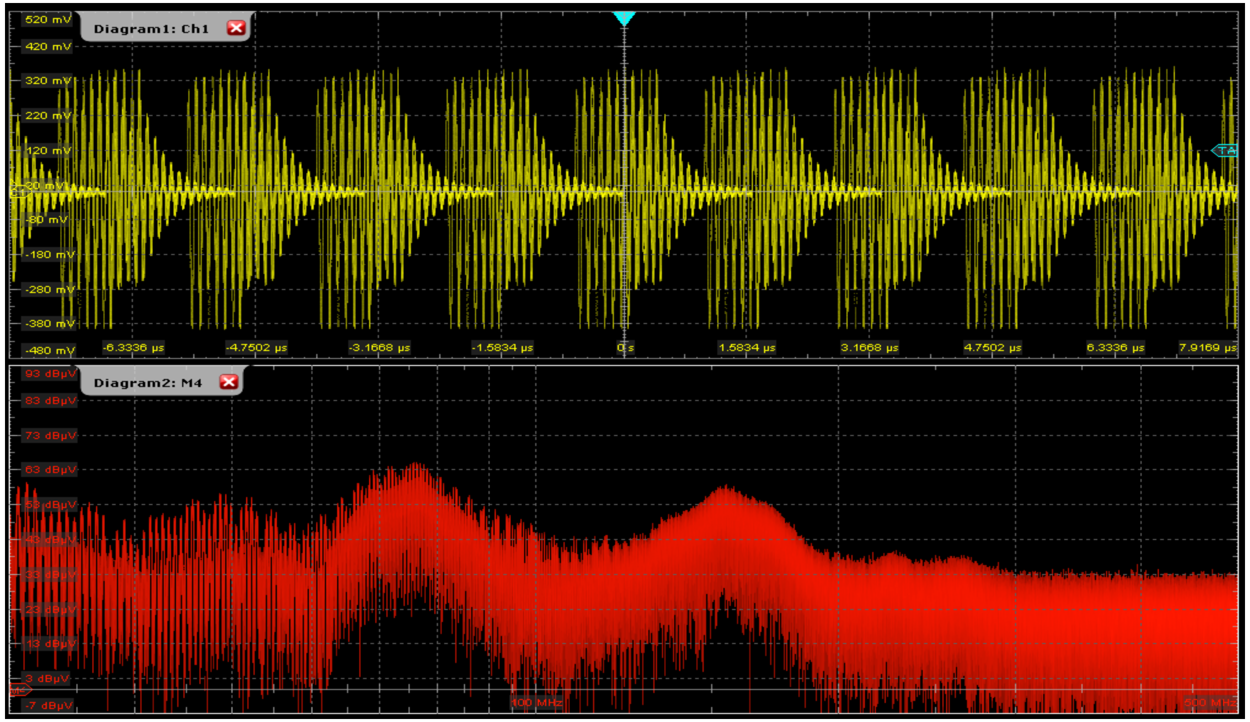




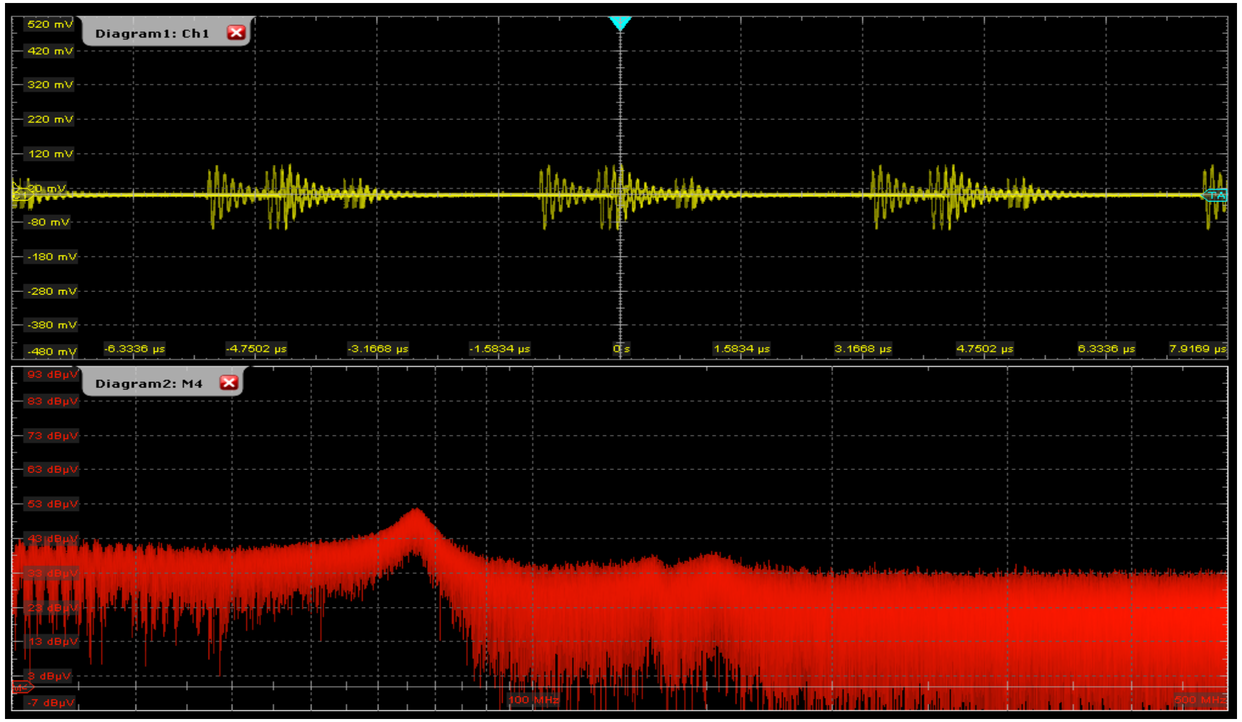
- Measured at the storage inductor
- Measured at the High Side MOSFET

➢ The reason for radiation is not the inductor for sure!

MEASURED WITH H-FIEL PROBE AT THE BOOSTRAP DIODE 30MHZ-500MHZ



- Boostrap Design (A)

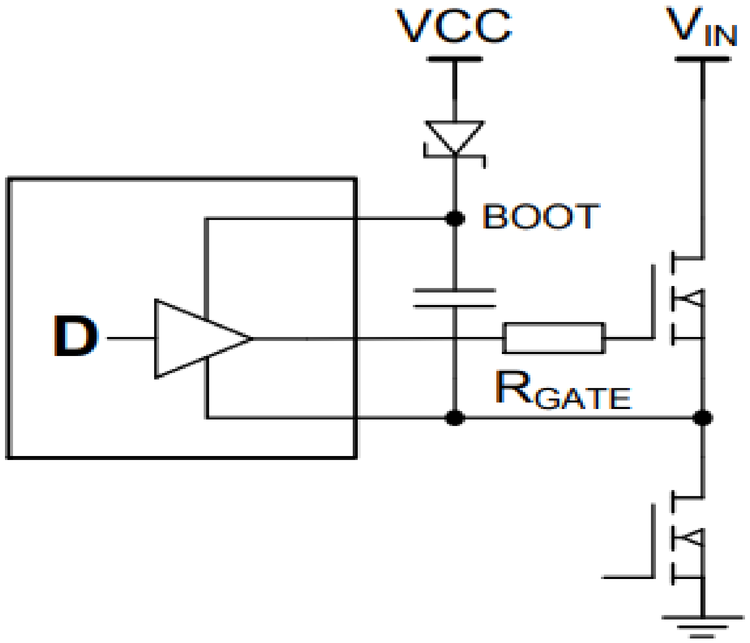


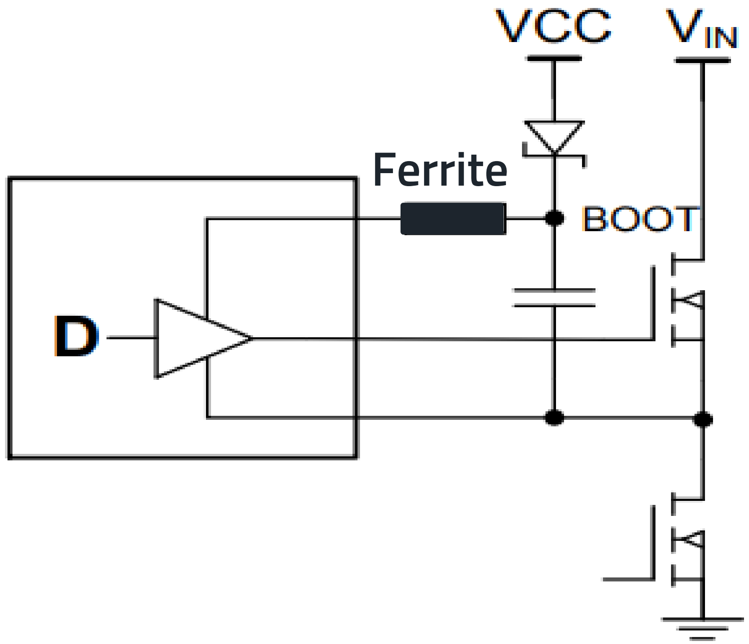
- Bootstrap Design (B)

➢ The improved layout and using an other diode improve of lot

ALTERNATIVE: FERRIT IN BOOSTRAP ADDED (WÜRTH ELEKTRONIK APPNOTE ANP025)

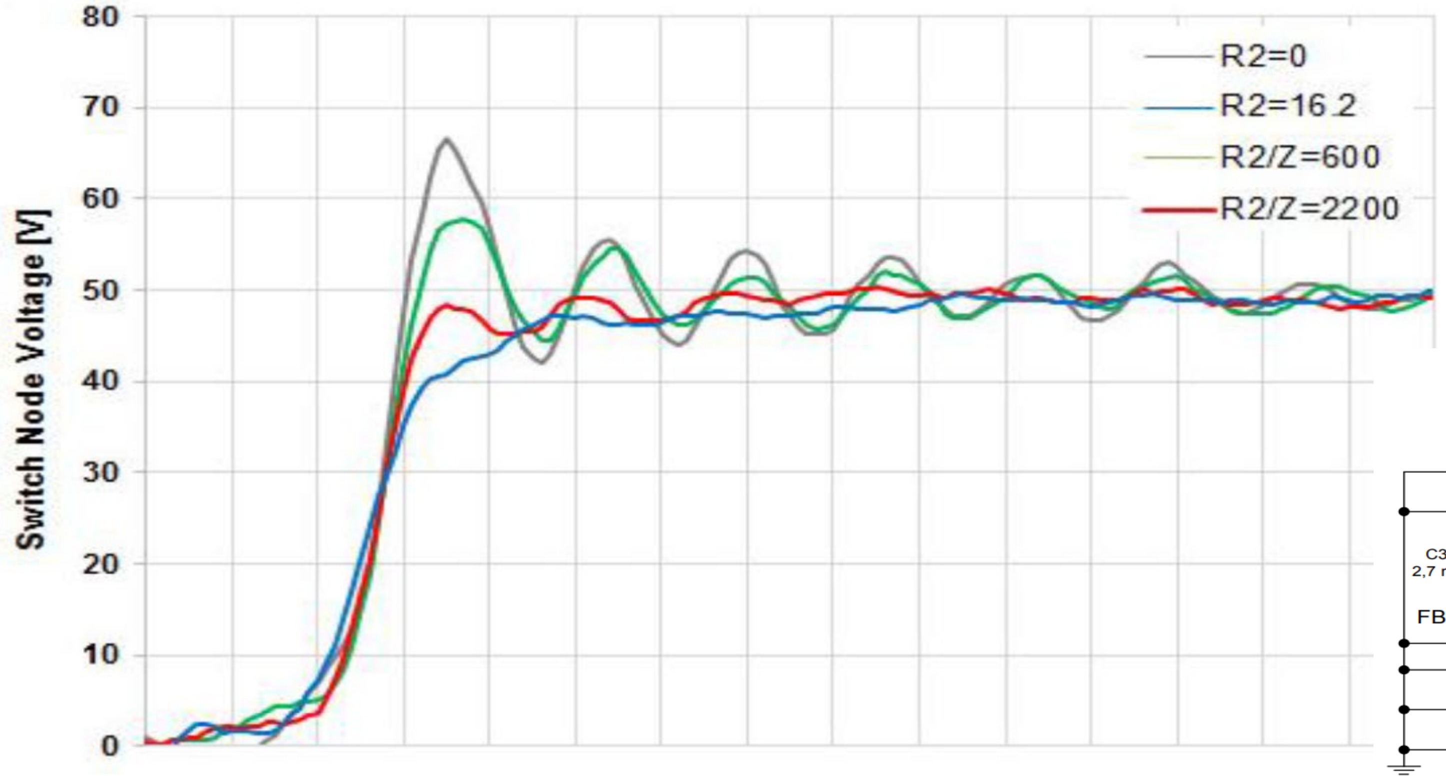
- Advantage: only the rise time afected → More efficient as using a resistor at Gate



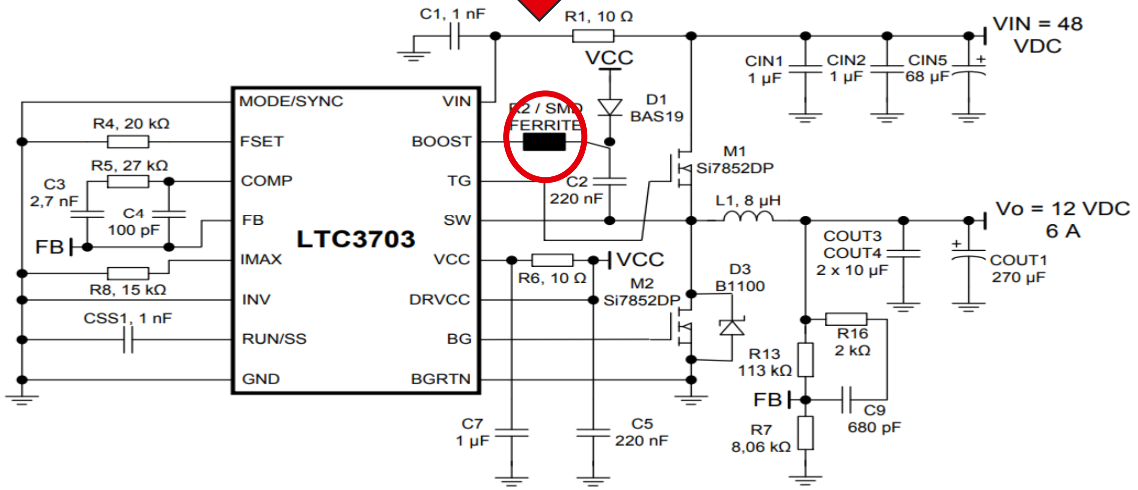


ALTERNATIVE: FERRIT IN BOOSTRAP ADDED (WÜRTH ELEKTRONIK APPNOTE ANP025)

- Measurement made by an LTC3703 Demo Board using different Boostrap resistors / Chip Bead Ferrite (CBF)

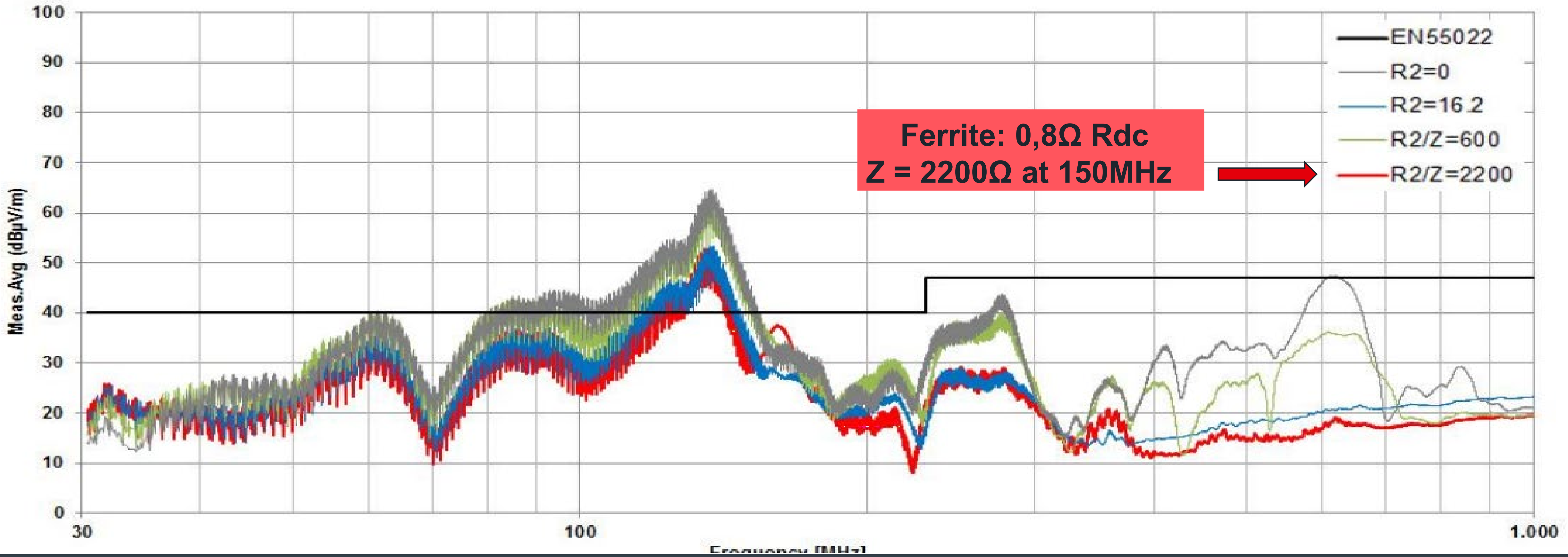


Ferrite: 0,8Ω RDC
Z= 2200Ω at 150MHz



ALTERNATIVE: FERRIT IN BOOSTRAP ADDED (WÜRTH ELEKTRONIK APPNOTE ANP025)

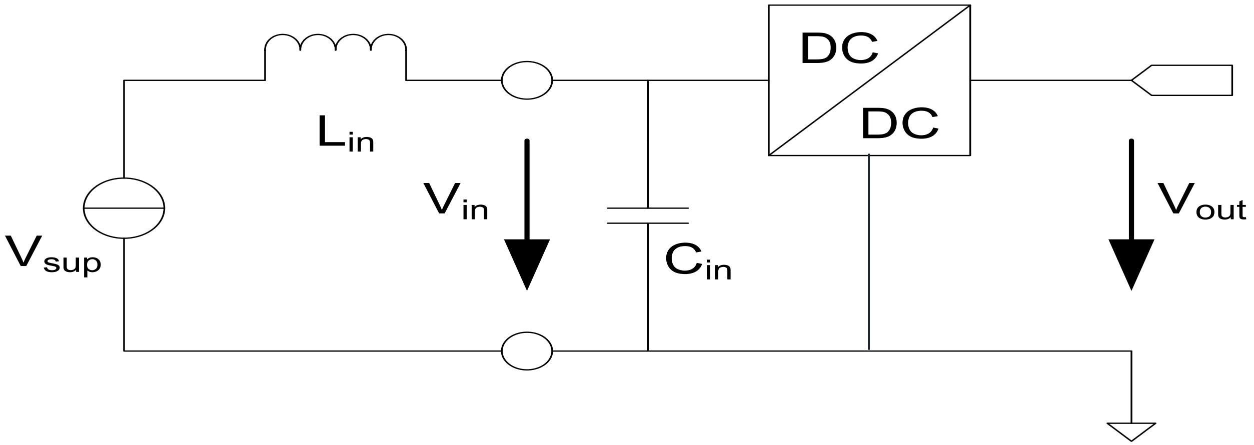
- EMC measurement made by an LTC3703 Demo Board using differnt Boostrap resistors & Chip Bead Ferrite (CBF)



FILTER DESIGN

„L“ Input filter

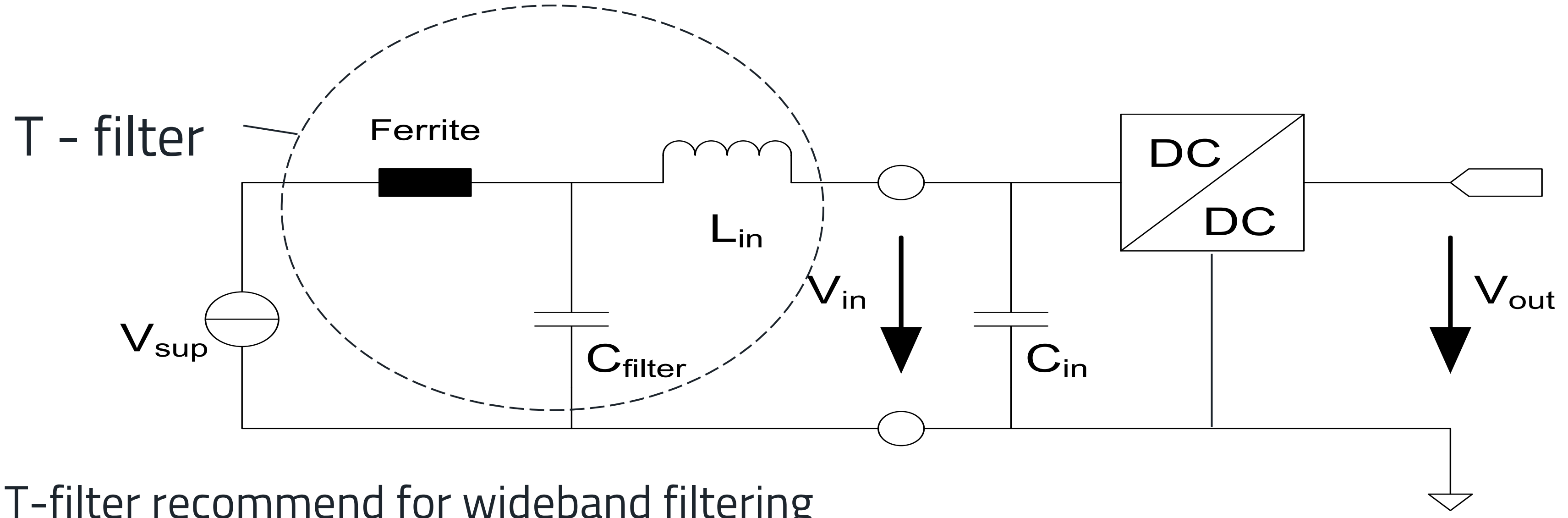
(minimal recommend filter)



- Simple L-Filter
  - Input filter reduce current ripple on input line
  - Input filter reduce differential mode noise on input line
  - Input filter reduce radiated emission via input traces

Attention!!! This filter is not efficient to reduce common mode noise on input lines

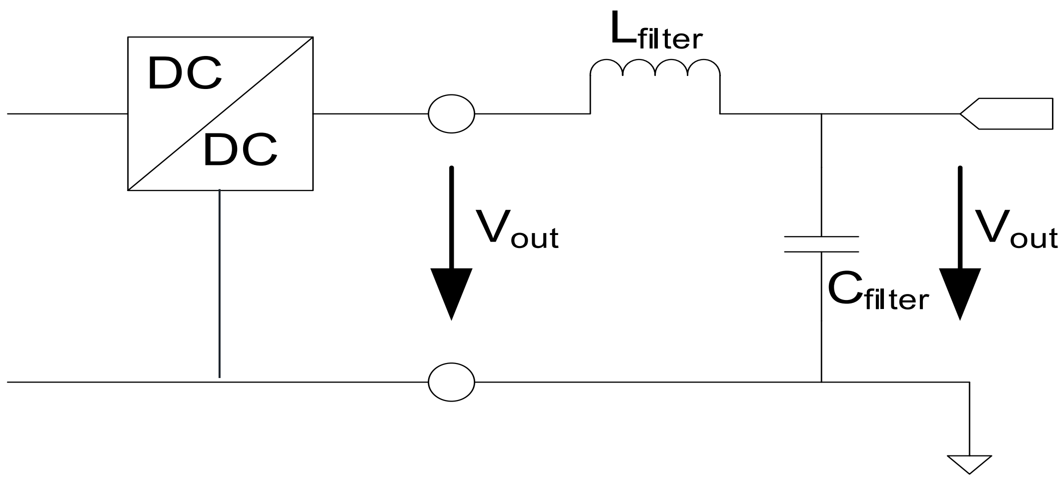
WIDEBAND INPUT FILTER
(RECOMMENDED FILTER SOLUTION)



- T-filter recommend for wideband filtering
  - L_{in} for low frequency filtering (DC/DC converter switching frequency)
  - Ferrite for high frequency filtering
  - C_{filter} shorting AC noise to GND (220pF < C_{filter} < 1nF, low ESR)

Attention!!! This filter is not efficient to reduce common mode noise on input lines

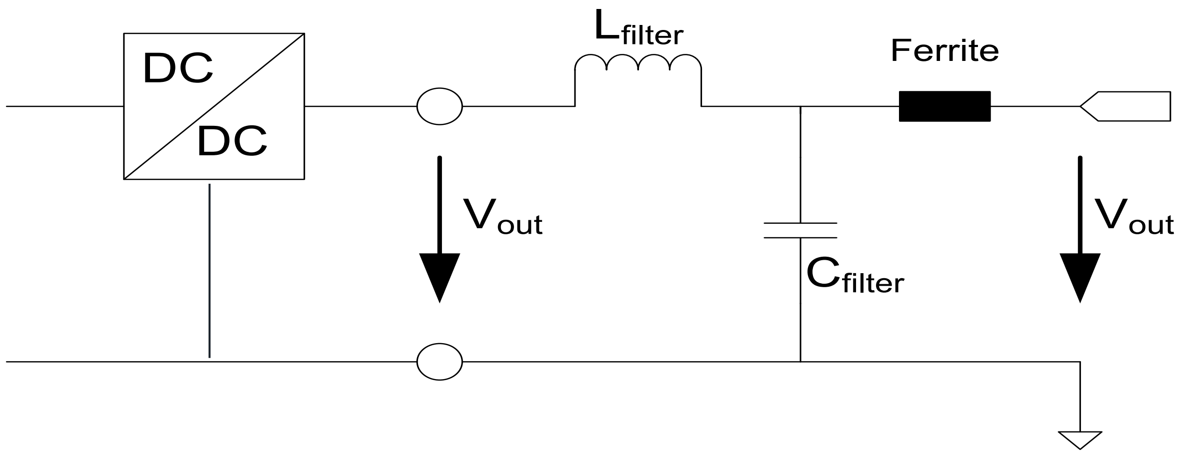
„L / C“ OUTPUT FILTER
(MINIMAL RECOMMENDED FILTER)



- Simple L/C Filter
  - Output filter reduce voltage ripple on output traces (Conducted Emission)
  - Output filter reduce radiated emission via output traces (Radiated Emission)
  - No optimal solution for radio power devices

Attention!!! This filter is not efficient to reduce common mode noise on output lines

„T“ - OUTPUT FILTER
(RECOMMENDED FILTER SOLUTION)

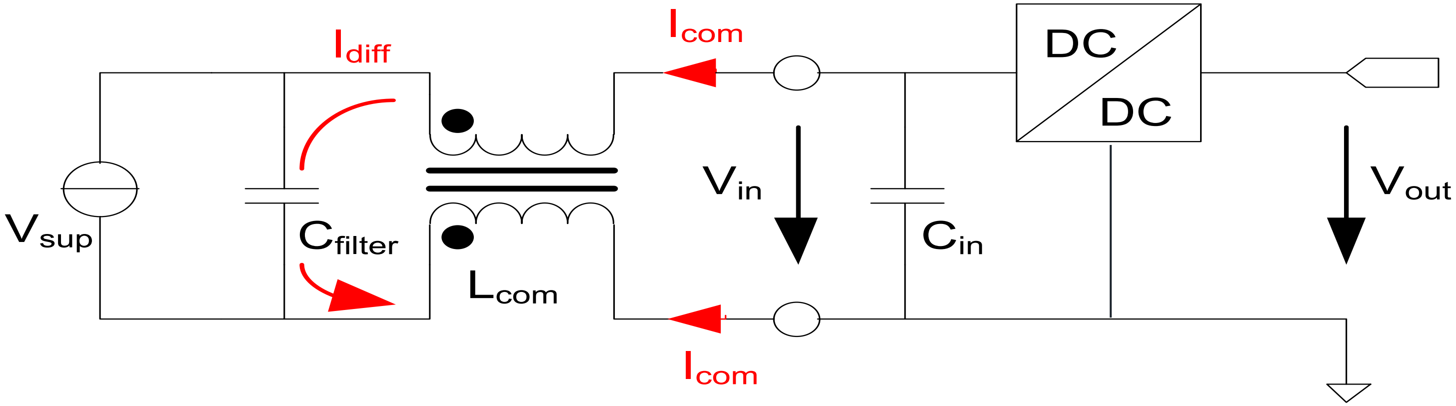


T-filter recommend for wide bandwidth filtering

- L_{filter} for low frequency filtering (DC/DC converter switching frequency)
- Ferrite for high frequency filtering
- This kind of output filter is for powering radio devices high recommended

Attention!!! This filter is not efficient to reduce common mode noise on output line

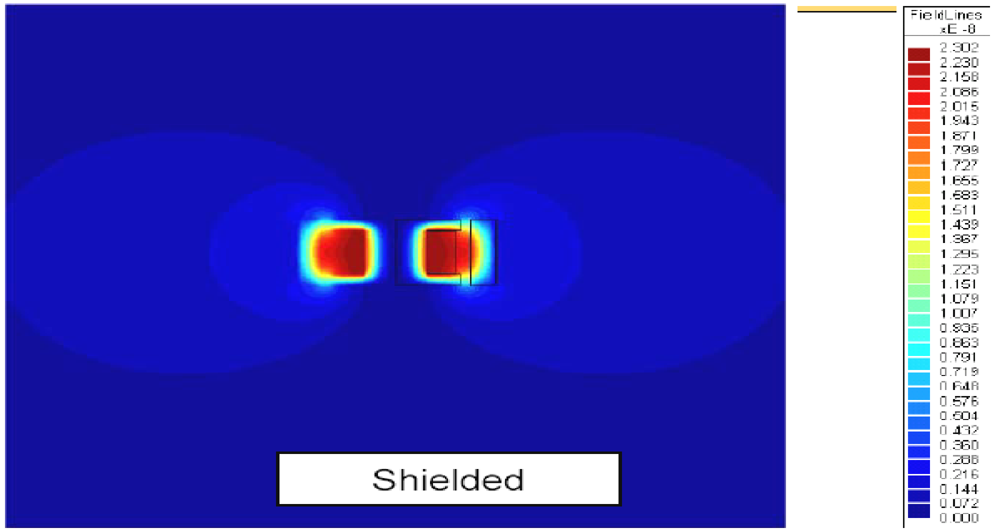
DECOUPLING COMMON MODE NOISE

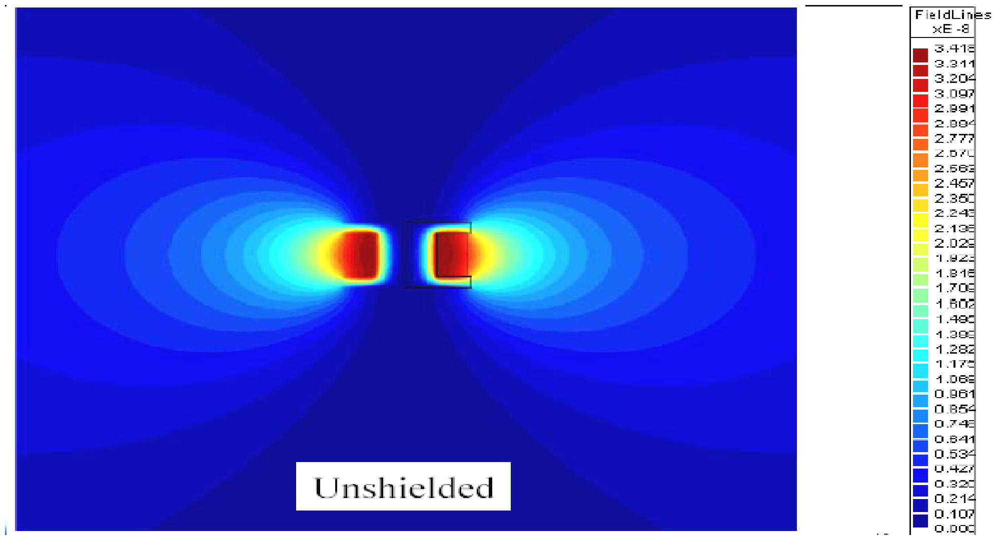


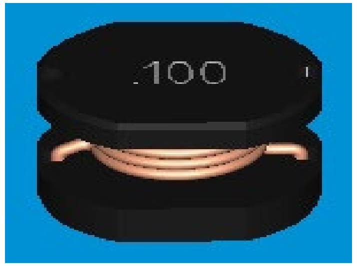
- For common mode rejection use common mode chokes
- For supplying over long distance common mode chokes are recommended
- Additional capacitor reduce differential mode noise
  - Small value for ceramic capacitor is recommended
  - Capacitor and common mode choke act as a LC - filter for differential mode noise
- Can be used for input and output lines

SHIELD VS. UNSHIELD

MAGNETIC FIELD LEAKAGE







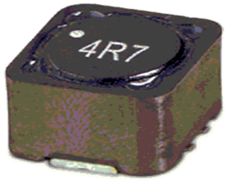
RADIATION BY INDUCTOR

WE - PD2 unshielded

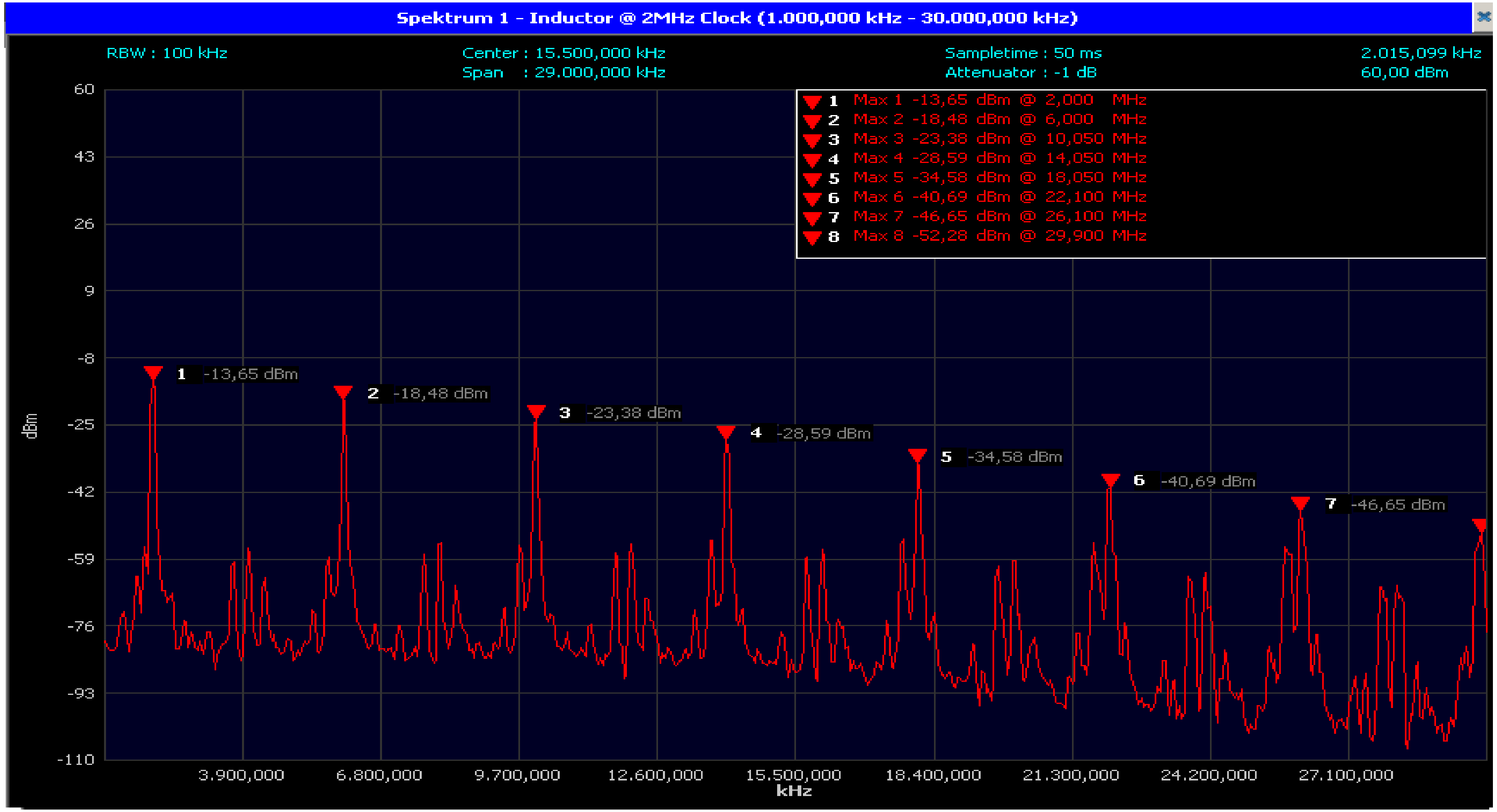
10µH, 2MHz Clock, 1A

WE – PD shielded

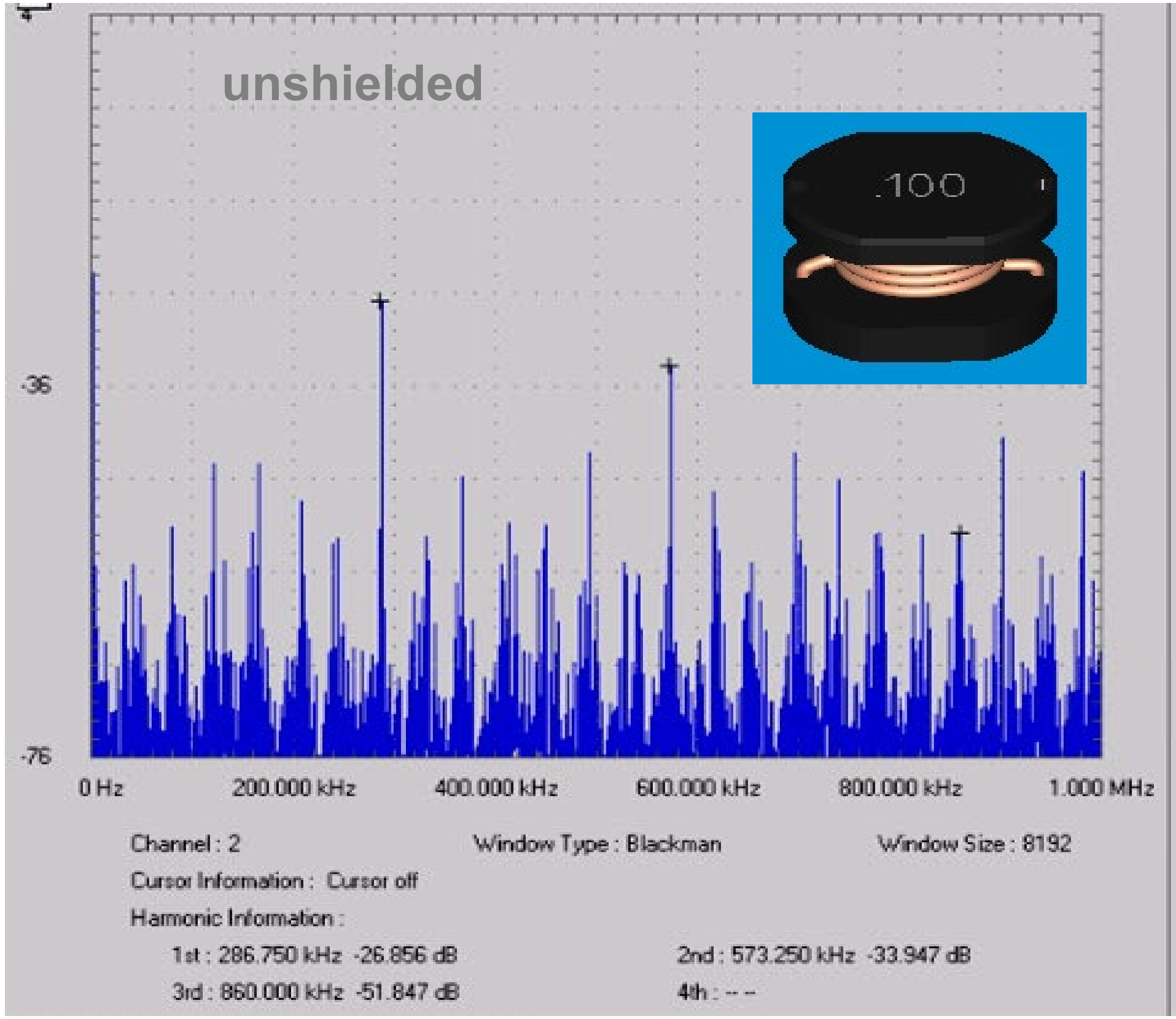
10µH, 2MHz Clock, 1A

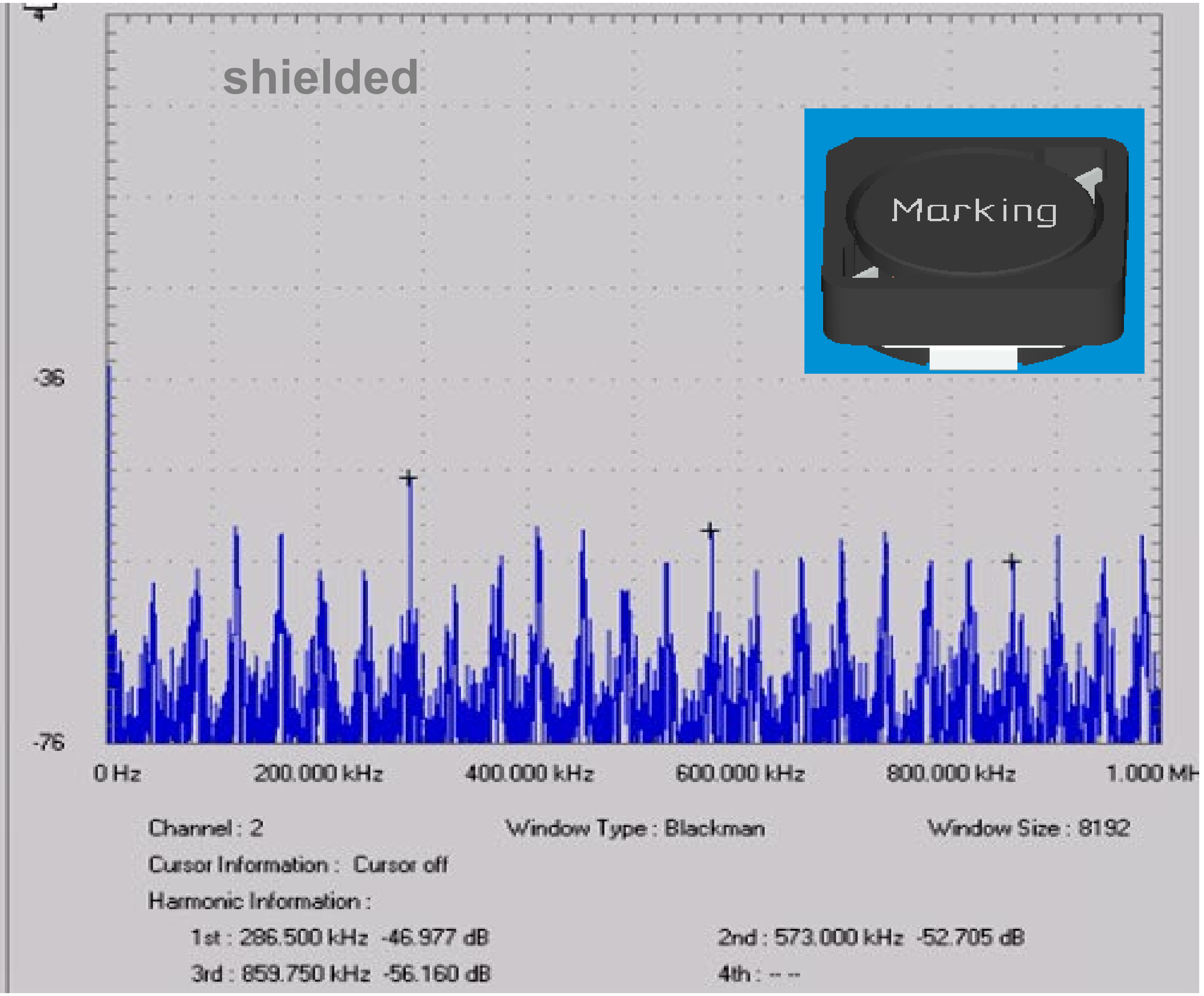


19dBm difference



Magnetic leakage shielded vs. unshielded





TRILOGY OF MAGNETICS

- 1. LTspice Book

  How to use and build spice models

- 2. Trilogy of Magnetics

  Design Guide for EMI Filter Design, SMPS & RF Circuits

- 3. Trilogy of Connectors

  Basic Principles and Connector Design Explanations

- 4. ABC of Power Modules

  Functionality, Structure and Handling of a Power Module

- 5. ABC of Capacitors

  Basic principles, characteristics and capacitor types

TECHNICAL SUPPORT NEEDED?

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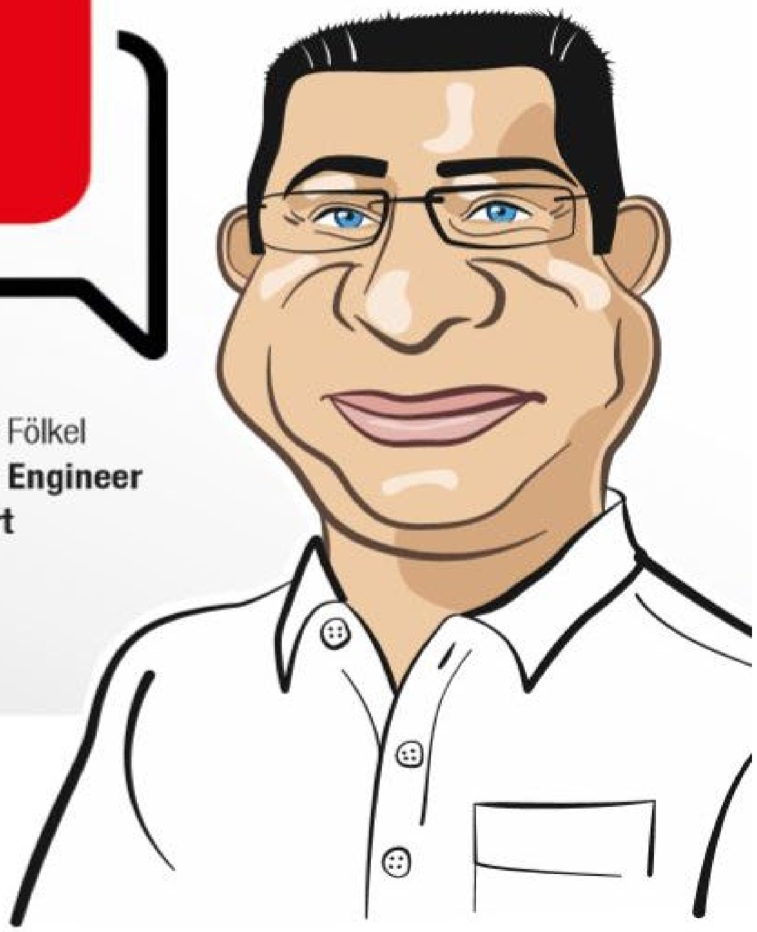

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